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RESEARCH INSTITUTE, NEW DELHI.

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# CONSTITUTION\*

## ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

## ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

## ARTICLE III

*Voting members:* Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

*Associate Members:* Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

## ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

## ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

## ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

\*As revised and adopted at the Boston meeting, December 29, 1946.

## BY-LAWS

Section 1—*Duties of Officers*: The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve *ex officio* as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve *ex officio* as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve *ex officio* as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve *ex officio* as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee*: There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, the Editor-Business Manager, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee*: There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nomination Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee*: There shall be a committee on program consisting of five (5) members, including the Secretary and the Editor. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee*: There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Editor in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the PROCEEDINGS. The Committee at the call of the senior member shall elect a chairman from among its members, who shall serve for the calendar year.

The Committee shall appoint an Editor and Business Manager of the PROCEEDINGS, subject to the approval of the Executive Committee. He shall serve for a period of 3 calendar years, and shall be charged with editing, publishing and



distributing the PROCEEDINGS. He shall serve *ex officio* as a member of the Executive Committee.

Section 6—*Membership Committee*: There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee*: There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements*: There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum*: Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues*: The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws*: The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups*: Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the PROCEEDINGS of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches*: A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the PROCEEDINGS.

Section 14—*Term of service for elected officers*: The term of service for elected officers shall be from the close of the annual meeting at which they are elected until the close of the next annual meeting.

## Foliar Diagnosis: Internal Bark Necrosis in Young Apple Trees<sup>1</sup>

By WALTER THOMAS, WARREN B. MACK, and FRANK N. FAGAN,  
*Pennsylvania Agricultural Experiment Station,  
State College, Pa.*

IN one of the Collège experimental orchards used as a pruning experiment, which in 1941 was planted to Stayman, Delicious, and Rome varieties on nursery stocks, a large number of the trees of all three varieties began to show certain bark abnormalities which, when first noticed in 1944, were thought to be the result of spray injury; but more recently many of the trees have developed bark symptoms one characteristic of which resembles the condition known as "measles", more specifically to the type of non-parasitic apple bark disease characterized by Berg (1) as "internal bark necrosis".

The symptoms in most trees are relatively mild; on one of the trees (I 10), however, they are severe. Some of the trees as indicated in Table I and figures show necrotic areas indicated by the brown or dark color of the inner bark and the appearance of brown spots or flecks as seen in freshly cut sections.

A simply and necrotic condition of the inner bark of Delicious apple trees growing in sand nutrient cultures was reported by Young and Winter (8), to be the result of boron deficiency. This conclusion was later confirmed by Hildebrand (3), who also grew the trees in sand cultures. In Hildebrand's experiments, Delicious apple trees in nutrient solutions without boron showed stunting, rosette, bronzing of terminal leaves, internal bark necrosis and dieback, the early stages of which were characterized by spherical necrotic areas in the phloem which usually enlarge, joining neighboring areas and causing elevations ("pimples") on the surface. Hildebrand found that application of borax to the soil in orchard field experiments with trees showing the above boron deficiency symptoms "greatly reduced bark symptoms and stimulated a more vigorous growth".

In a recent note Berg and Clulo (2) stated that they have been unable to produce any necrotic lesions or other symptoms typical of internal bark necrosis on the bark of Red Delicious trees grown in boron-free sand cultures, although other symptoms of boron deficiency such as stunting of the trees, procumbent growth of twigs, and rosetting were in evidence. Nor did the application of borax to the soil of diseased trees in orchards of Berg's experiments correct the disease.

These investigators, however, obtained positive results with additions of manganese and iron salts in greenhouse and orchard field experiments, the disease apparently being associated with high amounts of manganese (and also iron) in the bark and leaves of diseased trees.

Hildebrand (4) in a more recent abstract reports that the soil around severely affected trees of Delicious apple was extremely acid (pH 3.8 - 5.0), very low in bases, and contained toxic concentrations

<sup>1</sup>Authorized for publication on July 25, 1947, as paper No. 1382 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

of Al, Fe, and Mn. Correction of the faulty soil conditions required the application of both Ca and Mg.

### EXPERIMENTAL

The orchard, as was stated previously, was planted in 1941, with permanent trees of Stayman, Delicious, and Rome spaced 40 by 40 feet, and filler trees of the same varieties were spaced alternately, midway between the permanent trees in the rows, in one direction, making the planting distance 20 by 40 feet. Filler trees were ringed annually after the fourth season, to bring them into bearing as early as possible, but during the 1945 season many ringed trees died during a drouth after which all filler trees were removed at the end of the season. The land on which the orchard was planted had been devoted to general farm crops, of which the yields had been good. During the first two seasons after planting, the rows were cultivated and the intervening strips were planted with sweet clover; thereafter, the entire area was planted with Ladino clover to which 4-12-4 fertilizer was applied annually, except in 1945, at the rate of about 300 pounds to the acre. The growth of both the trees and the cover crops in general has been good.

Because the fruit crop was destroyed in 1945 and severely reduced in 1946 by late spring freezes, no yield nor growth records have been taken in this orchard.

The orchard consists of 12 rows of Stayman divided into two blocks of six rows each, with eight trees in each row, between which three rows of Delicious and three of Rome are interspersed.

A preliminary trial on the end trees in each row was made in 1944 by means of applications of borax or potassium sulfate, or both. These applications were made before any samples were taken for analysis, without, however, any definite evidence that any improvement in the symptoms has been effectuated thereby during the next season or the year following (1946). These results, therefore, are in accord with the experience of Berg and Clulo (2).

In 1945, after an exploration of the whole orchard, leaf samples were taken periodically during the season from 21 of the trees including all three varieties, and analyses were made for nitrogen, phosphorus, potassium, calcium, magnesium, boron, manganese, and iron.

### RESULTS

Table I shows the mean (resultant) values for the growth cycle of each of the elements determined. Fig. 7 presents the relationship between nitrogen and phosphoric acid throughout the cycle and Fig. 6 the resultant NPK-units and intensities.

Fig. 1 to 5 inclusive show the superficial appearance of the bark of certain trees chosen to represent several degrees or types of bark abnormalities observed in 1945. Fig. 1 shows a portion of a branch about 2 inches in diameter, with marked roughness of the bark surface, and numerous brown lesions of bark tissue, which would be revealed by tangential sectioning. Fig. 2 illustrates roughness of bark surface on a Stayman tree branch of about the same diameter as that



FIG. 1. I 10 Stayman, most severe necrosis observed, with marked roughness of bark.

in Fig. 1, but without internal bark necrosis. Figs. 3 and 4 show a branch of a Rome tree, in which some internal bark necrosis was found in 1945, and which illustrates a type of enlargement found on many trees. The surface of the bark of this tree was generally normal in appearance, with relatively few rough areas, except the enlarge-



FIG. 2. C 16, Stayman, roughness of bark without internal necrosis.



FIG. 3. B 8, Rome, with some necrosis in 1945, and local enlargement caused by woody inclusions in the bark, which were not necrotic; bark surface mostly normal.

ments, which were found to enclose woody inclusions in apparently healthy bark tissue, from which the inclusions could be separated readily. Fig. 5 shows injury on a Rome branch, localized in extent, and

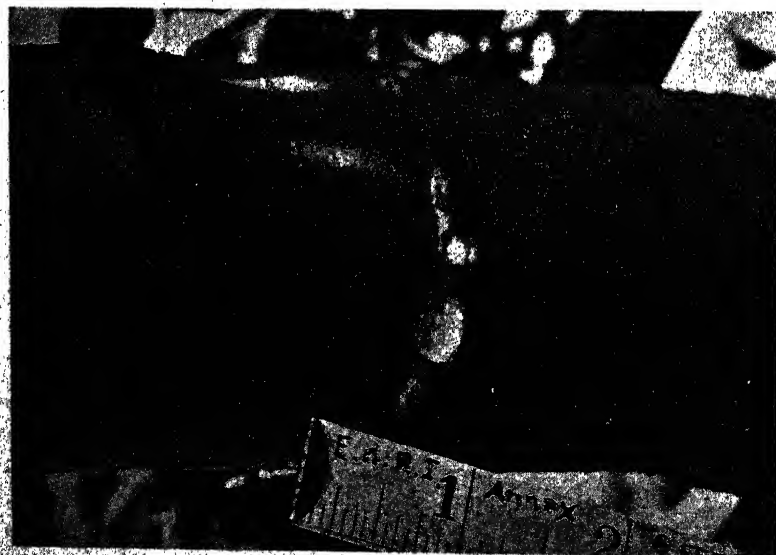


FIG. 4. B 8, Rome bark sectioned, showing no necrosis. Same branch as in Fig. 4.



FIG. 5. F 8, Rome, spray injury from oil mixture.

attributed to injury from oil sprays. The inner bark in this injured area showed fairly general browning near the surface.

TABLE I—COMPOSITION OF LEAVES FROM APPLE TREES OF THREE VARIETIES SAMPLED PERIODICALLY DURING THE GROWTH CYCLE (RESULTS EXPRESSED IN TERMS OF DRIED MATERIALS)

Tree No.	N Mg/ Gm	P Mg/ Gm	K Mg/ Gm	Ca Mg/ Gm	Mg Mg/ Gm	Mn γ Gm	Fe γ Gm	B γ Gm	Condition in 1945
<i>Stayman</i>									
A4	21.5	4.23	12.4	16.9	2.86	38.0	235	24.0	Healthy
A6	20.5	5.10	14.1	10.2	3.04	36.6	220	22.3	Bark rough, no necrosis
A8	21.6	6.81	13.1	17.2	3.04	44.0	225	27.1	Bark rough, no necrosis
A10	21.5	5.53	15.6	14.1	2.95	60.3	145	28.2	Bark rough, slight necrosis
A12	19.6	3.73	15.0	13.1	3.47	37.3	285	35.8	Healthy
A16	20.9	4.11	15.3	13.6	2.74	63.5	275	34.2	Bark rough, no necrosis
C16	20.6	3.97	16.2	13.1	3.18	47.0	260	39.4	Slight roughness, no necrosis
I10	19.8	5.53	16.4	12.7	2.76	42.0	155	30.8	Bark rough, severe necrosis
K8	19.9	4.36	16.6	12.5	3.34	48.0	175	29.2	Relatively healthy
<i>Delicious</i>									
B2	22.1	6.35	16.1	13.1	3.16	61.1	235	28.0	Bark rough, no necrosis
B6	23.1	6.28	18.1	14.5	2.92	55.0	245	29.7	Bark rough, no necrosis
B8	23.2	5.26	16.4	13.9	2.88	57.1	155	27.3	Bark rough, necrosis
B10	23.1	5.86	17.4	16.2	3.15	63.5	230	32.7	Bark rough, no necrosis
B14	23.4	5.58	16.2	18.0	3.60	97.6	155	32.0	Bark little rough, no necrosis
B16	23.4	4.83	17.8	13.7	3.41	58.0	150	28.5	Bark rough, necrosis
<i>Rome</i>									
F2	20.8	7.81	17.7	20.2	3.33	68.2	225	31.3	Bark rough
F6	22.1	5.73	14.6	15.8	3.42	53.1	250	28.8	Healthy
F8	20.2	5.72	21.1	16.8	3.09	57.2	175	34.2	Bark rough, necrosis
F10	21.8	5.43	17.2	13.5	3.56	51.6	270	31.5	Healthy
F16	19.2	4.26	19.4	12.3	3.55	69.0	165	40.0	Bark little rough, no necrosis
H16	20.4	5.23	18.2	11.4	3.47	48.4	155	33.2	Bark little rough, no necrosis

**Manganese:**—Berg reports<sup>2</sup> values of 86 to 300 micrograms per gram of dried leaf material in healthy trees and 1200 to 3200 micrograms per gram in severely diseased trees, the analysis being based on leaves taken from twigs that became badly diseased during the first growing season. These values are much higher than those of our orchard, in which the range is from 36.6 to 97.6 micrograms per gram of dried leaf material for all trees and from 42.0 to 60.3 micrograms per gram for the necrotic trees I 10, F 8 (spray injury), B 8, B 16, and A 10. Moreover, there is no relation between severity of symptoms and manganese content revealed in Table I; for the most severely necrotic tree has a manganese content lower than some of the relatively healthy trees.

In certain trees reported by us in another investigation (6), some of which were of the same age and variety as in this investigation and none of which showed any bark necrosis, the manganese content of morphologically homologous leaves ranged from 50 to 70 micrograms per gram of dried foliage.

There is therefore, no apparent relationship of the manganese uptake to bark symptoms in the trees under investigation.

**Iron:**—From greenhouse experiments Berg and Clulo (2) concluded that not only excess manganese but also excess iron may be important factors in the development of the disease. The iron content of the tissues of healthy and diseased trees has not to our knowledge been reported by them.

The range in the present experiment is 145 to 285 micrograms per gram. In general the iron content of the necrotic trees is lower (50 to 60 per cent) than that of those showing no necrosis. But there are two exceptions, Romes F 16 and H 16, in which bark roughness without necrosis occurs, and in which the iron content is of the same order of magnitude as those of necrotic trees.

Vigorous trees D 32, C 32, C 31, and D 31 reported in another experiment (6) have an iron content ranging from 138 to 140 micrograms per gram, and trees of the same age as those of this experiment, B 9 and D 2, a content of 84 and 117 micrograms per gram respectively. In all cases comparisons are made between morphologically homologous leaves. These results, therefore, do not indicate that iron is a factor in this experiment.

**Boron:**—All values for boron shown in Table I are above the known critical limit for this element; leaves from trees showing bark roughness without necrosis have in many cases a lower content of boron than those from necrotic trees, although the differences are not large.

As in experiments previously reported (7) no consistent relationship is found between the values for calcium and boron.

**The Major Elements:**—Both in greenhouse and field experiments Berg and Clulo (2) noticed that a long season and ideal growing conditions were conducive to the development of internal bark necrosis. This might suggest some relationship to vigor, of which the intensity of nutrition and the balance between the fertilizer elements are im-

<sup>2</sup>Berg, Anthony, Private communication, November 1, 1946.

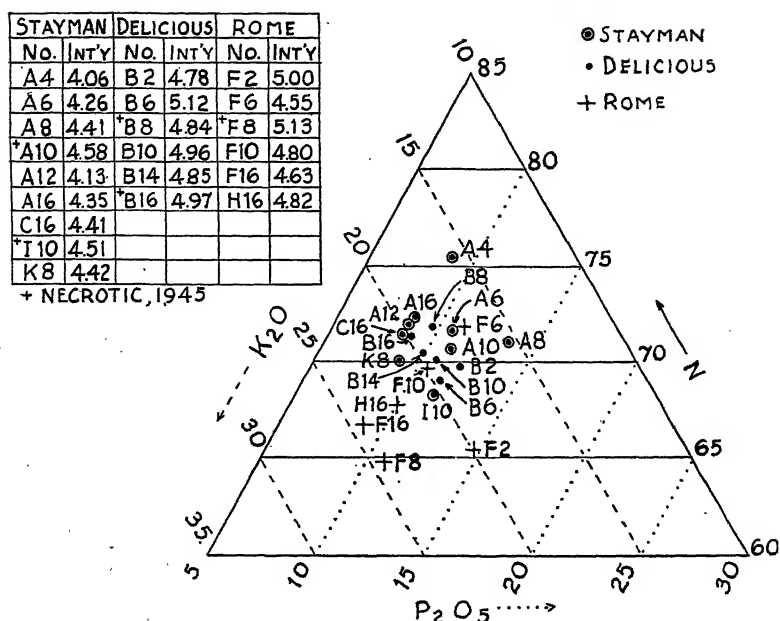


FIG. 6. Loci of the resultant NPK-units and mean intensities of nutrition of the Stayman, Delicious, and Rome trees examined in 1946.

portant indications. Unfortunately, growth records for these trees are not available and it is not possible, therefore, to examine the relationship of intensity of nutrition and the NPK-equilibriums (5) to growth and development.

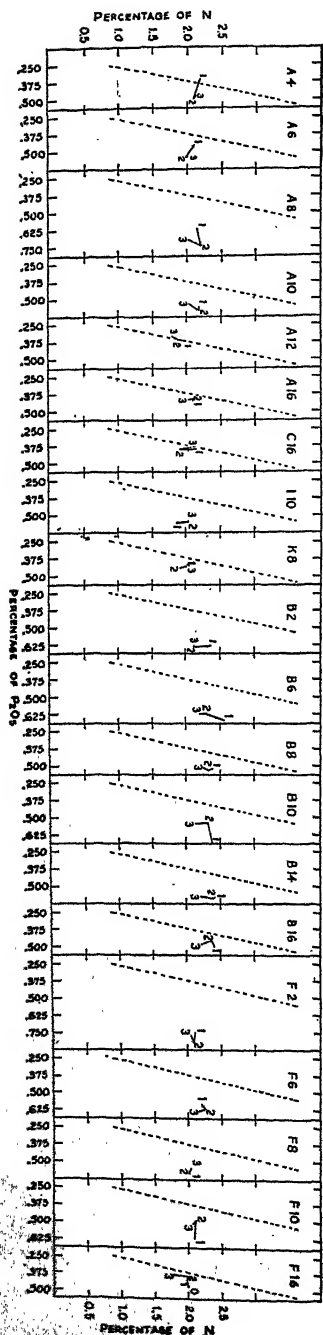
Fig. 6 shows the resultant NPK-units and intensities in these trees. The necrotic trees in diminishing order of severity are I 10, F 8, B 8, B 16, A 10 and with the exception of F 8 which is probably the result of spray injury, these are all congregated within a small area. Noting the locus of A 12, one of the most vigorous trees, suggests an examination of the imbalance between N and  $P_2O_5$ . This is shown in Fig. 7.

The equation to the line (broken) joining the loci of the healthy tree A 12 is  $Y = 3.23x - 0.43$  which is the general type for optimum equilibrium in apple trees. For example the N- $P_2O_5$  equilibrium of the most vigorous high yielding tree C 32 of a previous report (6) is represented by the equation  $Y = 3.45x - 0.038$ , the general type for optimum equilibrium. The departure from equilibrium between N and  $P_2O_5$  in the other trees is shown in magnitude and direction to be considerable.

## DISCUSSION

The data of Table I show that in no case are any of the elements determined deficient as based on known critical values. Within a given variety there is a relatively wide range particularly for iron and manganese; but the data for these two elements afford no suggestion that





they are causal factors in bark necrosis nor is there any evidence that the symptoms are the result of boron deficiency.

In respect to the major elements there are relatively large differences in the uptake of a particular element even among the trees of the same variety. The extent of the imbalance has been determined, the principle feature being the displacement of the equilibrium between nitrogen and phosphoric acid in nearly all trees throughout the cycle. To what degree this imbalance is a causal factor in the disease has yet to be determined, nevertheless it does not appear as yet that the disease seriously threatens the development and growth of any of the trees except I 10; in others, symptoms detected in 1945 appeared to diminish during the favorable growing season of 1946.

#### SUMMARY

The nutrition of young apple trees of several varieties certain of which in 1944 and 1945 exhibited bark abnormalities resembling those described by Berg as internal bark necrosis was examined by the method of foliar diagnosis. The severity of the disease was not found to be associated with the concentration in the leaves of any of the minor elements for which analyses were made, namely iron, boron, and manganese; in fact, the concentrations of these three elements varied through ranges which are considered to be normal by many investigators.

FIG. 7. Relationship at the different periods of sampling of nitrogen and phosphoric acid content of dried foliage from apple trees sampled in 1946. The dotted line represents the equilibrium between N and  $P_2O_5$  in tree A 12, represented by the equation  $Y = 3.23x - 0.43$ , the general type for optimum equilibrium in apple trees. The numerals 1, 2, 3, and 4 represent the successive period of sampling.

The nitrogen-phosphoric acid ratio, however, was found to be unbalanced, and the extent of the imbalance in general was directly related to the severity of the symptoms observed.

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# The Winter Hardiness Complex in Deciduous Woody Plants<sup>1</sup>

By W. G. BRIERLEY, *University of Minnesota, St. Paul, Minn.*

THE effects of low temperatures on plants have been studied for more than a hundred years. These studies and observations have resulted in publication of over 3,400 articles on hardiness as listed by Harvey (12) in 1935. All these and later studies indicate the great amount of attention which has been given to the problem of hardiness and indicate its varied and puzzling nature. From the background of many investigations carried on at Minnesota and elsewhere, a concept has gradually developed that winter hardiness is a complex of several specific factors. The purpose of this paper is to present this concept for discussion and further study in the hope that it may aid in the solution of some of the puzzling problems which confront those studying hardiness expressions in woody horticultural plants.

In earlier studies of the problem, the hardiness of a woody plant has been defined by its overall ability to escape injury during the varying conditions of winter weather over a period of several years. Relatively little consideration has been given to the specific factors involved in the injuries. Many records show only survival or the degree of injury sustained. Attempts to distinguish between hardy and tender varieties by various methods, the breeding of plants for superior hardiness, and studies of the inheritance of hardiness often have produced no clear cut results mainly because the complexity of the hardiness problem has not been realized. Variations in injury to fruit trees which occurred under different winter conditions in Michigan were reported by Bradford and Cardwell (3). Dorsey and Bushnell (11) pointed out that hardiness is by no means a simple relationship, but, if progress is to be made, the concept of complexity must be developed beyond that point. No attempt is made in this paper to survey all the literature on hardiness. Its purpose is to call attention to the need for investigations dealing with specific factors relating to ability of woody plants to survive winter conditions. There is need to recognize clearly that several factors are involved in survival or injury in order that we may correctly distinguish between those which aid in survival and those which may be the direct cause of injury. Some of these factors, shown in Table I, long have been recognized, but others, particularly those relating to cold resistance, seem to have escaped attention until recently. Marked differences in the hardiness ratings of some fruit plants grown in northern and southern regions possibly may be reconciled when the roles of all the factors of the hardiness complex are better understood.

## NEW VARIETIES MAY AFFECT OLD STANDARDS

It seems likely also, that we should re-examine some of our old hardiness standards in light of the behavior of the large number of

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TABLE I—FACTORS OF THE HARDINESS COMPLEX

- I. *Basic Factors*
  1. Condition of plant
  2. Variety
  3. Maturity
  4. Exposure
- II. *Water Relations*
  5. Winter desiccation
- III. *Temperature Relations*
  6. Rest period
  7. Dormancy
  8. Time of development of cold resistance
  9. Rate of development of cold resistance
  10. Ultimate or absolute cold resistance
  11. Retention or loss of cold resistance
  12. Ability to regain cold resistance

new varieties which have been introduced within recent years. It is possible that some of these new varieties may possess characteristics which may effect material changes in old standards. Patterson (16) has suggested that the roots of some new fruits grown in the prairie provinces must have resistance to low temperatures greater than shown in the commonly accepted ratings. Recent studies by Brierley and Landon (5) of the cold resistance of roots of the relatively new raspberry variety Latham have shown much lower danger and killing points than Carrick (7) found in old varieties. Such differences suggest the interesting possibility that new varieties of other fruits may similarly change other old standards of hardiness.

#### HARDINESS A COMPLEX OF MANY FACTORS

When the term "hardiness" is used merely to imply ability of wood plants to survive winter conditions, the term lacks value because it is not specific. Records appearing in annual reports of the Minnesota Agricultural Experiment Station relative to survival of raspberry canes illustrate the confusion which may follow our failure to realize that several specific factors are involved. In 1916 Dorsey (9) reported that the Latham raspberry, then identified as "Minn. No. 4",—"was not injured by a temperature of 49 degrees F below zero when left uncovered." In 1920 (10) he added the apparently contradictory note, "The winter was mild for all fruits except raspberries and strawberries". From these statements we may infer that mild injury to raspberry canes occurred in a severe winter and severe injury in a mild winter. When these statements are considered in light of information now available it is apparent that both statements were sound and that "hardiness" is much more complex than merely ability to survive low temperatures. If results of investigations conducted under different climatic conditions are to be related, the particular factor or

factors concerned must be recognized. At present some of the factors discussed herein must be considered as not fully proven, since there is little evidence relating to them. It may be that subsequent studies will show that other factors need to be included. The several factors which now appear to be properly included in the hardiness complex are briefly discussed here.

### I. BASIC FACTORS

1. *Condition of the Plant*:—This factor needs only brief discussion here as its relation to hardiness is fairly well understood. A well-grown woody fruit plant, adequately supplied with stored foods, in good health, and not weakened by insects or by production of heavy crops in general will be best able to survive winter conditions.

2. *Variety*:—Differences between varieties relative to winter survival long have been recognized. Old varieties have been accepted in localities where they survive and thrive and have been rejected where they have failed. Ability of new varieties to endure winter conditions usually is determined, at least for the place of origin, before they are named and introduced. In general, however, it should be recognized that the variety merely expresses its reaction to winter conditions and that recording the performance of varieties does not explain differences between them. Knowledge of the role of specific factors is needed to explain why varieties usually considered hardy may at times be severely injured in winter.

3. *Maturity*:—Full maturity long has been accepted as a primary requirement of hardiness. Although maturity of woody plants is not readily defined, the relationship between indices of maturity such as completion of current season shoot growth or shedding of leaves, and cold resistance in the apple has been shown by Hildreth (13), Wilson (17), and others. The great difficulty relating to this factor, however, is the tendency to attribute to immaturity the effects of some entirely different factor. Maturity is necessary before a plant can develop resistance to cold but does not indicate that hardening has occurred. If a mature plant for some reason does not develop its highest degree of resistance to cold, injury during subsequent cold weather cannot properly be attributed to immaturity. Similarly if a matured and hardened plant fails to retain its resistance to cold, any subsequent cold injury is not related to the stage of maturity. Brierley and Landon (6) found that injury to raspberry canes commonly attributed to immaturity has at times been due to a rapid loss of cold resistance during a few mild days in winter. Meader and Blake (15) and Blake and Steelman (2) have reported a similar fluctuation in cold resistance of peach buds. Injury following such changes in cold resistance obviously is not related to maturity and should not be so recorded.

4. *Exposure*:—This factor needs little discussion as its effects long have been recognized. It is one of the reasons why windbreaks and shelter-belts are used, and also is the main reason why small plants such as the raspberry are protected in winter in northern localities by a covering of soil. A point that should not be overlooked, however, is that species native to northern localities are not necessarily hardy, but

may escape injury when protected either naturally or by management practices. Brierley and Hildreth (4) showed this to be the case with low-bush blueberry species native to northern Minnesota.

## II. WATER RELATIONS

5. *Winter Desiccation*:—This factor relates to drying of woody plants during the dormant season. In this, as in other factors, there has been confusion in the interpretation of results because woody plants tend to dry following injury due to cold, warm spells, insect injury, or disease. Such drying easily is confused with true desiccation injury. When drying occurs it is necessary first to determine if it is the cause or a result of injury. It is well known that the water content of woody plants adapted to northern regions, when fully matured in fall, comprises half or more of the fresh weight of the young wood. This water content may fall and rise during winter, and slight losses cause no material injury. When a large part of this water is lost some plants, or their younger wood, cannot recover. Desiccation occurs most commonly in the Great Plains area where the soil freezes deeply and where drying winds are frequent. Some investigators believe that drying occurs even when the soil is not frozen because roots take up water slowly from cold soil. Under such conditions water may be lost more rapidly than it is replaced and drying may proceed beyond the point where recovery is possible. If woody plants are to be considered "hardy" under such conditions, they must be able to survive desiccating conditions as well as low temperatures. Thus, the problem of hardness is complicated and is further confused if the cause of drying is not determined accurately.

## III. TEMPERATURE RELATIONS

6. *Rest Period*:—The resting condition in woody plants generally is considered an internal inhibition of growth, but external factors such as cold, heat, injuries, anesthetics, and so on are known to be effective in "breaking" rest. Brierley and Landon (6) have shown that although rest in the raspberry is relatively intense in early October this condition is easily upset by early cold and that buds then may become active during only a few mild days in winter. This very rapid development of bud activity has led directly to severe injury to raspberry canes during subsequent cold.

Darrow (8) working with blueberries and Magoon and Dix (16) studying response of the grape have shown that rest ends relatively early in these fruit plants. Possibly these fruits do not become active in mild weather as quickly as the raspberry but we may properly question if onset, intensity and duration of rest may be more directly related to injury or survival in some plants than we have realized. Behavior of the raspberry suggests the possibility that the peculiar reaction of some other woody plants to winter conditions may be similarly explained.

7. *Dormancy*:—When rest is not the controlling factor most woody

plants are unable to grow, or are dormant at temperatures below about +41 degrees F. When rest is broken and bud temperature rises above 41 degrees F, growth in its early stages may begin. It seems likely that in late winter or early spring, growth may begin at temperatures somewhat lower than 41 degrees F. There appears to be a marked difference, however, between various woody fruit species in their temperature requirements for growth. The raspberry seems to respond at lower temperatures than apples and plums. At least the reputedly hardy Latham raspberry frequently has been severely injured by cold after winter mild spells whereas adjacent mixed variety plantings of apple and plum have shown no injury. Our information relating to dormancy and growth requirements could well be increased to the advantage of those studying the hardiness problem.

8. *Time of Development of Cold Resistance*:—Cold resistance usually begins to develop during moderately cold nights and mild days in fall. It seems likely that woody plants adapted to northern regions develop cold resistance early, but there may be marked differences between kinds and varieties. If early cold causes injury this does not indicate inability to harden eventually, but may show that a given plant is not adapted to a northern locality because of delayed hardening. This has been recognized by some investigators. Time of hardening may be more important than hitherto considered and more information is needed on this item.

9. *Rate of Development of Cold Resistance*:—Information is meager relative to the effects of this factor upon ability of woody plants to escape injury from low temperatures. Available information deals largely with the behavior of herbaceous plants, but Brierley and Landon (6) recently have shown that in the Latham raspberry cold resistance develops rapidly. We may surmise that in the Armistice Day blizzard of 1940 in Minnesota, Haralson, Wealthy, McIntosh and Northwestern apple varieties escaped serious injury because of ability to harden rapidly, whereas the less hardy varieties, Jonathan and Delicious, were injured because of inability to harden as rapidly. As the temperature in the area adjacent to St. Paul did not fall below 0 degrees F during that storm, nor during the several days following, the ultimate cold resistance points for these varieties was not reached. As all apple varieties in the locality appeared to be well matured, injury under the circumstances prevailing could be attributed neither to immaturity nor to severe cold. A somewhat similar comparison between Duchess and Jonathan was shown graphically by Hildreth (13) (Fig. 3 p. 25) in 1926 although ability of Duchess to harden more rapidly than Jonathan was not discussed.

As it is not unusual in late autumn and early winter in northern regions for the temperature to fall rather rapidly to points near 0 degrees F, it may be that ability to harden rapidly is an important characteristic of "hardy" varieties. We need to learn much more about the role of this factor in relation to the hardiness ratings of varieties.

10. *Ultimate Cold Resistance*:—This factor, sometimes called "absolute" hardiness is a variety characteristic. It is the lowest tempera-

ture which a given variety can survive without injury under the most favorable conditions. Although cold resistance of leaf buds, flower buds, and stem tissues may differ within a variety, hardiness ratings usually have been based upon the behavior of the vegetative portions of a woody plant. To a large extent, hardiness ratings such as those of Hildreth (13) and of Beaumont and Hildreth (1) for apple varieties are expressions of this factor. Such ratings usually show the average behavior of varieties over several years. They are fairly reliable, and different ratings agree fairly well. Some ratings are based on studies carried on under controlled temperatures, but many more such studies are needed to broaden our information on the subject. Presumably, for a given variety and location, maturity, rest period, and cold resistance, all may have ultimate values which may not ordinarily be reached. Seldom would all these factors be likely to reach their ultimate values in the same season.

11. *Retention or Loss of Cold Resistance*:—Ability of a woody plant to develop a high degree of resistance to cold has a lessened value relative to survival if this resistance is easily lost. The common belief has been that hardiness once acquired is retained throughout the winter, then lessens more or less rapidly towards spring. Hildreth (13) believed that this was the case, and perhaps it is typical behavior for the apple, but evidence now available indicates that the cold resistance of some woody plants may vary widely during winter. Meader and Blake (15) and Blake and Steelman (2) have shown that cold resistance of peach buds is not uniform but increases and decreases during winter. Similarly Brierley and Landon (6) have shown that the high degree of cold resistance in the Latham raspberry is quickly lost during periods of mild weather. Behavior of peach and raspberry suggests the possibility that the poor survival record of some other woody fruit plants may be due to loss of a protective degree of cold resistance rather than to failure to develop it. Thus ability to retain resistance to cold in relation to survival appears to be another factor of importance in the hardiness complex. It is evident that our information relative to this factor is incomplete.

12. *Ability to Regain Cold Resistance*:—Do our woody plants re-harden easily and quickly if cold resistance is lost during mild spells in winter? Blake and his associates (2, 15) have shown that cold resistance in peach buds may be lost and regained repeatedly thus showing ability to re-harden. That so little is known about the ability of woody fruit plants to re-harden probably is related to our lack of information about variations in or loss of cold resistance. Obviously such information is needed before the problem of hardiness can be fully understood.

Certainly we need to know when cold resistance is developed, how rapidly it develops, the ultimate degree of resistance, behavior relative to retention or loss of cold resistance, and much more about ability to re-harden. Contributions dealing with hardiness, winter injury, or ability of woody plants to survive winter conditions will be much more useful if they deal with these or other specific factors of the hardiness complex.



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## The Clustering Habit in Haralson, Minjon and Wealthy Apples<sup>1</sup>

By W. G. BRIERLEY, *University of Minnesota, St. Paul, Minn.*

IN general, the over-all value of the numerous apple varieties introduced within recent years makes them more acceptable in commercial orchards than old-time varieties. The desirable characteristics of these new varieties may far outweigh their poor ones, but the latter need to be recognized. Clustering, or multiple set, is one of these undesirable characteristics. Some old varieties such as Wealthy have a reputation for clustering and in some localities, where this variety is grown, thinning is regularly practiced. Although the advantages gained by thinning are recognized, growers usually will prefer a variety which does not cluster.

As the relatively new varieties, Haralson and Minjon, have shown a tendency to set in clusters, thus suggesting the need for thinning, the extent of clustering in these varieties has been studied in comparison with Wealthy. These studies were carried on with Haralson in 1937, 1938, and 1939, with Wealthy during 1938 and 1939, and with Minjon in 1943 and 1944. The extent of clustering was recorded during seasons of heavy and light crops to note differences in variety behavior. Trees of different ages were included in the records to note the effect of age of tree on clustering.

The set of entire trees was recorded as it was noted that there was a definite increase in clustering towards the upper, better lighted parts of the trees. Because of this behavior, random samples of individual branches were not used. Also, in all three varieties in seasons of light crop, many branches were found with no set. During the study the behavior of 35 Wealthy, 60 Haralson and 25 Minjon trees was recorded and a total of over 46,000 spurs examined.

### EFFECT OF HEAVY AND LIGHT SET

The data show that the extent of clustering was materially affected by set. In all three varieties there was a higher percentage of clusters of two to six apples when the set was light than when it was heavy. This behavior has long been recognized as characteristic of Wealthy, although it usually has escaped mention in published descriptions. The behavior of young Haralson trees as affected by set is shown in Table I. The same trees were used over the three-year period that included two heavy and one light crops. Increasing age and production of the trees affected the results but were unavoidable. This table shows a marked increase in the percentage of clusters of two to six apples in the year of light set. No similar comparisons could be made of Wealthy trees twenty years of age or older. This variety is an alternate bearer and older trees tend to produce little or no crop in the "off" year. Older trees of Minjon show this same tendency so far as their performance has been recorded.

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TABLE I—CLUSTERING OF YOUNG HARALSON TREES AS AFFECTED BY HEAVY AND LIGHT SETS

Apples Per Spur No.	Heavy Set Six Years		Light Set Seven Years		Heavy Set Eight Years	
	No. Spurs	Per Cent Spurs	No. Spurs	Per Cent Spurs	No. Spurs	Per Cent Spurs
1.....	263	41.8	306	25.2	3,181	56.2
2.....	243	38.6	405	33.4	1,818	32.1
3.....	91	14.4	313	25.8	546	9.6
4.....	29	4.6	147	12.1	106	1.9
5.....	3	0.5	38	3.1	14	0.2
6.....	0	0	4	0.4	0	0
Total clusters per cent..		58.7		74.8		43.8

## EFFECT OF AGE OF TREE

The effect of age of tree on the percentage of clusters is shown in Table II. In Wealthy there was a slight increase in clustering on older trees, but as no trees 20 years of age or older were available the figures are not strictly comparable to those for Haralson and Minjon. The decrease in per cent of clusters on older trees was marked in Minjon and more so in Haralson. This table also shows that both young and old trees of Minjon tend to set much higher percentages of clusters than either Haralson or Wealthy.

TABLE II—CLUSTERING AS AFFECTED BY AGE OF TREES

Variety	Age of Trees (Years)	Per Cent Clusters of Two to Six Apples (Weighted Average)
Wealthy.....	7 to 8	43.8
	14 to 15	41.1
Haralson.....	6 to 8	50.1
	Over 20	39.6
Minjon.....	10 to 11	76.1
	24	69.7

## VARIETY HABIT

The clustering habit for the three varieties is shown in Table III. The records for all ages of trees and the varying sets of the different seasons are included in these weighted averages to express variety

TABLE III—CLUSTERING HABIT OF HARALSON AND MINJON COMPARED TO WEALTHY\*

Variety	Years Re-recorded	Spurs	Apples Per Spur						Total Spurs (Number)	Clusters (Per Cent)
			1	2	3	4	5	6		
Wealthy	2	Number	5,056	2,583	877	238	52	2	8,808	42.5
		Per cent	57.4	29.3	9.9	2.7	0.6	0		
Haralson	3	Number	15,530	8,367	2,918	841	161	6	27,823	44.2
		Per cent	55.8	30.1	10.5	3.0	0.6	0		
Minjon	2	Number	2,182	3,559	2,403	1,022	678	131	9,975	78.1
		Per cent	21.9	25.7	24.1	10.2	6.8	1.3		

\*Behavior of trees of all ages.

habit. This table shows that Haralson tends to cluster as much as or slightly more than Wealthy. Minjon is shown to set a much higher percentage of clusters than either Wealthy or Haralson. Haralson on the average tended to set single apples on a little more than half the spurs. Clusters of two and three apples were common, and spurs with four or five apples were found frequently. Clusters of six apples did not occur frequently enough to appear in the percentages. Such clusters usually were found on young trees or on those with a light set.

Clustering in Minjon was more pronounced than in either Wealthy or Haralson (Fig. 1). Single apples were found on only 21.9 per



FIG. 1. Typical clusters in Minjon a month before harvest.  
Percentages are shown in the table.

cent of the spurs examined. Nearly four out of every five spurs set clusters of two to seven apples, although only two spurs were found with a set of seven apples. In Minjon the combined percentages for three, four, five and six apples per spur amounted to 42.4 per cent, a figure equal to the total clustering in Wealthy and nearly equal to that of Haralson. In addition, 25.7 per cent of Minjon spurs set two apples.

The beneficial effect of setting only one apple per spur was largely offset in both Wealthy and Haralson, because in these varieties the spurs often are crowded so closely together on young wood that the single apples touch to form "ropes." Under favorable conditions these varieties also tend to form axillary fruit buds on strong shoots. Most of these as a rule do not set, but when they do "roping" is more pro-



nounced. Such "ropes" are more common with Haralson (Fig. 2) than with Wealthy under Minnesota conditions. This behavior possibly is related to the heavier production of Haralson trees. In Minjon "ropes" are not so common, possibly because few axillary blossoms are formed. The tendency for Haralson to form "ropes" has a direct bearing on thinning of this variety. In another experiment the effects of thinning Haralson showed that leaving one apple per spur had little effect on size or color, whereas thinning to 4-inch spacing resulted in marked improvement in size and color with little loss in yield per tree.

FIG. 2. A "Rope" of Haralson apples in late July before the single apples were touching.

## Magnesium Deficiency in Kieffer Pear Trees

By C. P. HARLEY, *U. S. Plant Industry Station, Beltsville, Md.*

A SMALL block of 35-year-old Kieffer pear trees located at the Plant Industry Station, Beltsville, Maryland, had been topworked in 1936 to a number of new pear selections. While examining these trees in the latter part of August 1946, it was observed that the older leaves at the base of some of the current season's Kieffer growth exhibited a very unusual patterning. Oblong islands of dark purplish brown to almost black tissue were arranged in rather orderly fashion between the parallel veins on both sides of the midrib, extending from the tip to the base of the leaf, in typical specimens. Some chlorosis at the margins of these intervenal islands was present in leaves where the symptoms were extreme. Fig. 1 illustrates variations in degree of ex-

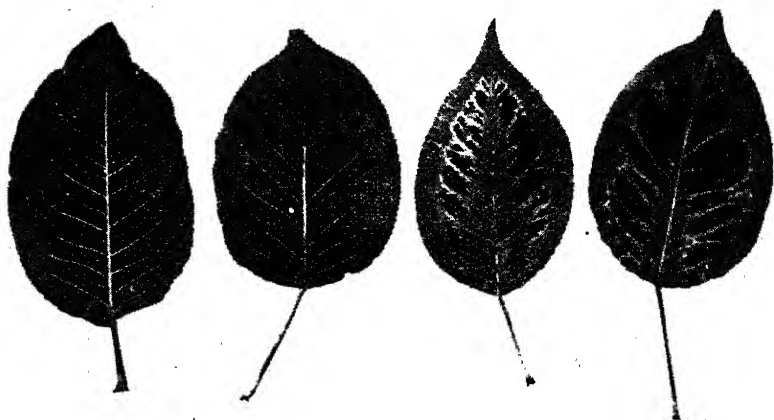


FIG. 1. Basal shoot leaves of Kieffer pear tree showing symptoms associated with low magnesium content, compared with a normal apical leaf.

pression, in comparison with a normal leaf of Kieffer. None of the grafted selections was visibly affected.

A deficiency of magnesium was suspected, for many young Golden Delicious apple trees growing in the immediate vicinity showed typical leaf symptoms of magnesium hunger. Corroborative evidence was obtained in the chemical analyses of the Kieffer leaves. These are given in Table I.

The very low magnesium and the rather high potassium percentages in the basal leaves indicate that the symptoms are associated with a deficiency of magnesium. The reciprocal relationship between magnesium and potassium in magnesium deficiency of the apple has been summarized by Boynton (1).

Although additional verification is perhaps desirable to definitely

TABLE I—NITROGEN, CALCIUM, POTASSIUM, AND MAGNESIUM CONTENT OF KIEFFER PEAR LEAVES, SAMPLED AUGUST 20, 1946 (EXPRESSED AS PERCENTAGES OF DRY WEIGHT)

Description of Leaf Samples	N (Per Cent)	Ca (Per Cent)	K (Per Cent)	Mg (Per Cent)
Leaves from basal portion of shoots showing characteristic symptoms.....	2.03	1.10	2.55	0.051
Leaves from terminal portion of the same shoots showing no symptoms.....	2.34	1.46	1.64	0.267

prove this condition to be due to magnesium deficiency, it is thought that a description of the unique and distinctive symptom pattern will be of interest at this time.

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## Comparative Value of Sawdust, Hay, and Seaweed as Mulch for Apple Trees

By L. P. LATIMER and G. P. PERCIVAL, *University of  
New Hampshire, Durham, N. H.*

APPLE orchards in New Hampshire usually are managed under some form of sod culture. In some orchards the grass is cut in summer and allowed to remain where it falls; or else it is raked up under the trees. Many growers have come to realize that greater benefits often are derived from bringing in additional mulching material, and spreading it under the trees. Meadow and marsh hay are usually used for this purpose.

In regions where it is difficult to obtain hay, sawdust often is readily available. Growers in these areas, therefore, have requested information concerning the possible use of sawdust for mulching their apple trees. To answer this question, an experiment designed to compare sawdust with hay and other materials as mulch for apple trees was begun in 1942 at the University Horticultural Farm. The set up for this experiment has been described in a previous paper (1). In brief, four rows of a young McIntosh apple orchard (7 years old) were selected for this experiment, and the mulch treatments begun in June 1942. Treatments were arranged in randomized blocks with six repetitions, but with the limitation that trees were paired according to circumference. Thus, there were trees of comparative diameters under each of the treatments in the different blocks. This was done in order to have trees of equal yield capacity represented in the different treatments. Yeager and Latimer (5) have shown that there is a very high positive correlation between tree circumference and yield of fruit in an adjacent block of older trees in this orchard. Thus, each block in the experimental design consists of four trees mulched with hay, four with pine sawdust, and four allowed to remain in sod without additional mulch. The grass growing between the rows and under the trees is cut each summer and allowed to remain where it falls. No fertilizer of any kind has been applied since starting the mulch treatments. In addition to the above treatments, 10 trees were selected in this same orchard and mulched with seaweed. This was done because one grower located near the seashore had used seaweed under some of his trees. This practice, in his opinion, gave excellent results. All data was subjected to statistical analysis. The soil in this orchard has been classified as Charlton stony loam, and averages 3 to 4 feet in depth.

### RESULTS

The first years results have been presented in a previous paper by the writers (1). The present paper is a progress report on the effects of the different treatments to date. The most important factors to consider from a commercial point of view are yield, color, and size of fruit.

Data for yield are presented in Table I. In 1943 and 1946 the yield of trees mulched with hay or with seaweed was significantly greater



TABLE I—YIELD (BUSHELS PER TREE)

Year	Soil Management				Level of Significance		
	Sod	Hay	Sawdust	Seaweed	P=0.05	P=0.01	F Value
1943.....	0.27	1.16	0.59	1.22	0.57*	0.82**	10.80**
1944.....	0.85	2.80	2.40	2.21	1.86	—	6.32*
1945.....	0.14	0.23	0.23	0.23	—	—	N.S.
1946.....	0.80	3.39	1.37	1.93	0.82	1.17	27.07**
Total 1943-6.....	2.06	7.49	4.59	5.59	2.25	3.20	14.41**

than that of trees mulched with sawdust or grown in sod. In 1944 trees mulched with hay yielded a significantly greater amount of fruit than trees in sod. The total yield for the four years of mulching treatment (1943 to 1946) was greatest in the case of trees mulched with hay. Seaweed mulched trees were second in total yield. Trees mulched with sawdust produced only 60 per cent as much fruit as those mulched with hay, while trees growing in sod produced a total of only 2 bushels of fruit per tree over the 4-year period.

Fruit size in 1944 and 1946, years of heavier yield, was not significantly different for the different treatments; but in 1943 hay-mulched and seaweed-mulched trees alike produced larger fruits than either trees mulched with sawdust or those growing in sod (Table II).

TABLE II—FRUIT SIZE (AVERAGE WEIGHT PER FRUIT (LBS.))

Year	Soil Management				Level of Significance		
	Sod	Hay	Sawdust	Seaweed	P=0.05	P=0.01	F Value
1943.....	0.31	0.36	0.31	0.37	0.023	0.032	22.42**
1944.....	0.32	0.32	0.32	0.28	—	—	N.S.
1945.....	0.28	0.32	0.28	0.30	0.020	0.029	11.87**
1946.....	0.24	0.23	0.23	0.24	—	—	N.S.

The fruit from sawdust-mulched trees and sod grown trees was more highly colored in 1943 than was fruit from trees under other treatments. In other years there was no significant difference in color of fruit attributable to different treatments except that in 1946 fruit from seaweed-mulched trees possessed less red color than fruit from trees under other treatments (Table III).

TABLE III—RED COLOR FRUIT (PER CENT SURFACE COVERED)

Year	Soil Management				Level of Significance		
	Sod	Hay	Sawdust	Seaweed	P=0.05	P=0.01	F Value
1943.....	84	68	86	64	9.3	13.3	10.90**
1944.....	83	79	76	80	—	—	N.S.
1945.....	69	69	71	70	—	—	N.S.
1946.....	73	72	75	61**	—	—	N.S.

In contrast to this, the ground color of fruit from hay-mulched trees and seaweed-mulched trees was darker green than was the ground color of fruit from sawdust-mulched or sod grown trees. In other

years the ground color was the same in all treatments except that in 1946 the ground color of apples harvested from seaweed-mulched trees was much darker green than that of fruit from trees under other treatments (Table IV). Regardless of the treatment there was a very

TABLE IV—GREEN GROUND COLOR (1 = YELLOW; 5 = DEEP GREEN)

Year	Soil Management				Level of Significance		
	Sod	Hay	Sawdust	Seaweed	P = 0.05	P = 0.01	F Value
1943.....	1.91	2.49	2.03	2.77	0.27	0.29	11.01**
1944.....	2.38	2.60	2.68	2.44	—	—	N.S.
1945.....	3.02	3.07	2.87	2.97	—	—	N.S.
1946.....	2.32	2.43	2.25	3.30**	—	—	N.S.

high *negative* correlation between the intensity or *darkness* of green ground color and the *total amount* of fruit surface covered with red color, the coefficient being greater in years of heavy crop than in years of light crop. The correlation coefficient for the several years was as follows:

	<i>r</i>	
1943.....	-.589	Light crop year
1944.....	-.753	Heavy crop year
1945.....	-.442	Light crop year
1946.....	-.689	Heavy crop year

The differential effect of treatment on leaf color was so marked that by sight alone one could easily distinguish trees which were under hay or seaweed mulches because of their dark green foliage. Leaves of sawdust-mulched, and sod grown trees were much paler green (Table V).

TABLE V—FOLIAGE COLOR (1 = YELLOW; 5 = DEEP GREEN)

Year	Soil Management				Level of Significance		
	Sod	Hay	Sawdust	Seaweed	P = 0.05	P = 0.01	F Value
1943 Fall.....	2.9	4.5	3.1	4.5	0.42	0.60	41.40**
1944 Spring.....	3.1	3.9	2.6	4.0	0.61	0.87	10.22**
1945 Fall.....	3.1	4.3	3.0	3.5	0.39	0.56	32.01**
1946 Summer.....	3.3	4.6	3.0	4.9	0.48	0.66	33.65**
1946 Fall.....	2.4	3.4	2.6	4.1	0.45	0.63	14.96**

The average annual length growth of terminal shoots was very uniform for all trees in the years preceding the application of the mulches. Following mulch application in the early summer of 1942, those trees mulched with hay made greater annual shoot growth than any of the others. There was no significant difference in length growth between the trees of the other three treatments, (Table VI). From 1943 to 1946, trees mulched with hay made about 30 per cent greater length growth than trees under any of the other treatments.

Although there was no significant difference in increase of trunk circumference due to difference in cultural method, the hay-mulched

TABLE VI—AVERAGE LENGTH GROWTH PER SHOOT (FEET)

Year	Soil Management				Level of Significance		
	Sod	Hay	Sawdust	Seaweed	P=0.05	P=0.01	F Value
1941.....	0.83	0.79	0.84	0.86	—	—	N.S.
1942.....	0.99	0.92	0.92	0.85	—	—	N.S.
1943.....	0.84	1.09	0.77	0.79	0.18	—	5.57*
1944.....	0.69	1.03	0.79	0.65	0.14	0.19	15.00**
1945.....	1.01	1.18	1.04	0.98	—	—	N.S.
1946.....	0.87	1.14	0.87	1.02	0.13	0.19	13.23**
Total 1943-6.....	3.41	4.44	3.47	3.44	0.46	0.66	15.29**

trees did seem to have a tendency to grow more in diameter than the others (Table VII).

In the fall of 1945, soil samples were taken. The results of quick-

TABLE VII—CIRCUMFERENCE OF TREE TRUNK (AVERAGE PER TREE FEET)

Year	Soil Management				Level of Significance		
	Sod	Hay	Sawdust	Seaweed	P=0.05	P=0.01	F Value
1940 sp.....	0.50	0.49	0.49	0.58	—	—	N.S.
1943 sm.....	0.83	0.82	0.82	0.91	—	—	N.S.
1944 sp.....	0.91	0.95	0.91	1.01	—	—	N.S.
1946 f.....	1.23	1.37	1.24	1.37	—	—	N.S.
Per cent increase 1940-6.....	48.2	67.1	51.2	50.6	—	—	N.S.

tests for available nutrient elements are presented in Table VIII. The different treatments did not seem to have any differential effect on pH. *Nitrate nitrogen* was much higher under hay than under other treatments. *Phosphorus* was higher, at the 0- to 2-inch level, under hay and seaweed mulches than under sawdust or sod; at the 2- to 4-inch level there was no such difference. At both levels, *Magnesium* was higher under hay mulch than under the other treatments, except that under seaweed mulch at the 2 to 4-inch level magnesium gave as high a test as was noted for hay mulch. *Potassium* was very high under all treatments, but seemed highest under hay. Available *calcium* did not differ among the different treatments. The hay mulch reduced the amount of soluble *aluminum*; no other treatment had this effect.

In the spring of 1946, hay mulched trees showed much heavier bloom than other trees under test. Unmulched trees were conspicuous for the low number of blossoms per tree. This condition was reflected in the yield of fruit as shown in Table I.

The difference in ability of each mulch to prevent weed growth was noteworthy. Grass and weeds did not grow up through the hay mulch, while the sawdust mulch formed an ideal medium for the growth of witch grass. At the end of the fourth year, the sawdust had become so filled with rhizomes of witch grass that, with the hand, it was difficult to dig through the mulch to the soil surface. Furthermore, witch grass readily grew up through the sawdust, finally hiding the latter from view. Grass grew vigorously at the edge of the seaweed, but did not grow up through it as readily as through the sawdust. The grass growing up at the edge of the seaweed mulch was

TABLE VIII—RESULTS OF QUICK-TESTS OF SOIL SAMPLES TAKEN OCTOBER, 1945 FROM BLOCKS TREATED WITH MULCHES INDICATED

Material	1	2	3	4	5	6	Seaweed
<i>pH (0- to 2-inch Level)</i>							
Sod.....	5.1	5.8	5.8	4.8	4.9	5.5	—
Hay.....	4.8	5.7	5.4	4.8	4.9	5.4	—
Sawdust....	5.3	5.1	5.5	5.1	5.3	5.8	—
Seaweed....	—	—	—	—	—	—	4.9
<i>pH (2- to 4-inch Level)</i>							
Sod.....	5.0	4.9	5.3	4.9	4.7	5.1	—
Hay.....	4.8	4.9	5.4	5.0	4.9	5.3	—
Sawdust....	4.9	4.7	5.2	5.2	4.8	5.5	—
Seaweed....	—	—	—	—	—	—	5.0
<i>NO<sub>3</sub>-N (0- to 2-inch Level)</i>							
Sod.....	VL	VL	VL	L	VL	VL	—
Hay.....	LM	M	M	M	M	M	—
Sawdust....	VL	VL	VL	VL	VL	VL	—
Seaweed....	—	—	—	—	—	—	VL
<i>(2 to 4-inch Level)</i>							
Sod.....	VL	VL	VL	VL	VL	VL	—
Hay.....	L	M	M	L	L	LM	—
Sawdust....	VL	VL	VL	VL	VL	VL	—
Seaweed....	—	—	—	—	—	—	VL
<i>NH<sub>3</sub>-N (0- to 2-inch Level)</i>							
Sod.....	L	L	L	L	L	L	—
Hay.....	L	L	L	L	L	L	—
Sawdust....	L	L	L	L	L	L	—
Seaweed....	—	—	—	—	—	—	L
<i>(2- to 4-inch Level)</i>							
Sod.....	L	L	L	L	L	L	—
Hay.....	L	L	L	L	L	L	—
Sawdust....	—	L	L	L	L	L	—
Seaweed....	—	—	—	—	—	—	L
<i>P (0- to 2-inch Level)</i>							
Sod.....	LM	L	LM	LM	L	L	—
Hay.....	M	M	M	M	M	M	—
Sawdust....	L	L	LM	LM	L	LM	—
Seaweed....	—	—	—	—	—	—	M
<i>(2- to 4-inch Level)</i>							
Sod.....	L	VL	VL	L	VL	VL	—
Hay.....	L	VL	L	L	L	L	—
Sawdust....	VL	VL	—	—	L	L	—
Seaweed....	—	—	—	—	—	—	L
<i>Mg (0- to 2-inch Level)</i>							
Sod.....	L	L	L	L	L	L	—
Hay.....	M	M	M	M	M	M	—
Sawdust....	L	L	L	L	L	L	—
Seaweed....	—	—	—	—	—	—	L
<i>(2- to 4-inch Level)</i>							
Sod.....	VL	VL	VL	VL	VL	L	—
Hay.....	L	L	L	L	LM	L	—
Sawdust....	L	VL	VL	VL	L	—	—
Seaweed....	—	—	—	—	—	—	L
<i>K (0- to 2-inch Level)</i>							
Sod.....	VH	H	VH+	VH	VH+	MH	—
Hay.....	VH+	VH+	VH+	VH+	VH+	VH+	—
Sawdust....	VH	VH	VH	H	VH	MH	—
Seaweed....	—	—	—	—	—	—	VH
<i>K (2- to 4-inch Level)</i>							
Sod.....	H	H	H	MH	M	M	—
Hay.....	VH	VH	VH	M	VH	VH	—
Sawdust....	H	MH	H	H	MH	MH	—
Seaweed....	—	—	—	—	—	—	VL

TABLE VIII—(Concluded)

Material	1	2	3	4	5	6	Seaweed
<i>Ca (0- to 2-inch Level)</i>							
Sod. ....	L	VH +	VH +	L	VH	VH	—
Hay. ....	VH +	VH	M	HVH	M	H	—
Sawdust. ....	H +	M	MH	M	H	MH	—
Seaweed. ....	—	—	—	—	—	—	M
<i>Ca (2- to 4-inch Level)</i>							
Sod. ....	L	L	H	VL	VL	L	—
Hay. ....	VL	L	L	VL	M	LM	—
Sawdust. ....	VL	L	L	LM	LM	MH	—
Seaweed. ....	—	—	—	—	—	—	M
<i>Al (0- to 2-inch)</i>							
Sod. ....	VH	H	H	VH	H	H	—
Hay. ....	H	M	M	H	M	M	—
Sawdust. ....	VH	VH	VH	VH	VH	H	—
Seaweed. ....	—	—	—	—	—	—	H
<i>Al (2- to 4-inch Level)</i>							
Sod. ....	VH	VH	H	VH	VH	VH	—
Hay. ....	H	H	MH	H	MH	MH	—
Sawdust. ....	VH	VH	VH	VH	VH	H	—
Seaweed. ....	—	—	—	—	—	—	VH

very dark green in color compared to the unfertilized grass growing between the rows.

The condition of the bottom layers of the various mulches appeared quite different after 4 years. A layer 2-inches thick of black, broken-down organic matter had accumulated under the hay mulch, and a considerable amount of this material had become admixed with the top-inch of soil. Feeding roots of the trees had grown into this layer. Evidence of decomposition was lacking under the sawdust, and the character of the soil had not changed apparently from its original condition. Under seaweed there was a slight accumulation of decomposed organic matter, and this had not become mixed with the soil.

The soil remained moist at all times under the hay and sawdust. Seaweed tended to dry out and shrink to such an extent that the top-soil also became dry during drouthy weather.

## DISCUSSION

There is strong evidence that under the conditions of this experiment, and in the absence of fertilizer application, hay mulch placed under the trees provided far better soil condition for tree development and root function than did sawdust; namely, by improving soil moisture conditions, increasing the organic matter content and the amount of available nitrogen, phosphorus, magnesium and potassium. At the same time the amount of soluble aluminum was reduced. Wander and Gourley (4) in Ohio, also have shown that minerals in available form increase under hay mulch. Shaw and Southwick (2) showed that striking amounts of nitrate accumulated in the soil under hay mulch in Massachusetts. In both cases above, no fertilizer was used with the mulches. Shaw and Southwick found also that there was greater shoot growth, trunk diameter increase, and yield with mulched trees than with those grown under cultivation without fertilizer. These facts sub-

stantiate the facts presented in this paper by the writers and lead to the conclusion that the improvement in performance of McIntosh trees mulched with hay has been due largely to the power of increasing soil fertility compared to the inability of the other treatments to do this. Furthermore, the hay mulch suppressed grass growth, thereby eliminating competition between tree roots and grass for minerals.

Although the amounts of available nutrients did not differ under sod and sawdust there was better retention of moisture under the sawdust. The pale green color of the leaves of trees mulched with sawdust indicated nitrogen deficiency. The same may be said for trees grown in sod. Further evidence that nitrogen supply was deficient under sawdust and under sod may be gleaned from the fact that in fall the leaves of these trees turned yellow and developed a considerable amount of pale pink color while the leaves of the trees mulched with hay and those mulched with seaweed still retained their good green color. Furthermore, fall defoliation occurred with sawdust-mulched and sod grown trees several weeks ahead of hay-mulched trees; in fact the green color of the leaves of the hay-mulched trees was retained until the time they were shed.

Data has been presented to show that trees mulched with sawdust respond in tree and leaf development much as do trees in sod, the difference between the two being manifest in the lighter yield shown by the trees in sod. This might seem to indicate that the leaf growth and twig growth had taken place at a time when there is the least competition for water and certain nutrients, but at the time of fruit bud formation water deficiency may have become a limiting factor with the trees in sod.

The effect of sawdust on plant growth when used as a soil amendment, and when used (as reported by Loree) as a mulch for raspberries, has been reported by Turk (3). Turk showed that sawdust, mixed with soil, or used as mulch, depresses the yield of non-leguminous crops and that this is associated with a decrease in available nitrates. If, however, the sawdust is mixed with the soil, this effect is temporary and may disappear in a year or two. If mixed with nitrates, there should be no harmful effect from sawdust, according to Turk. He further states that sawdust has virtually no fertilizing value. This is borne out by the data presented by the writers in Tables I to VIII.

The effects of sawdust compared with other materials as a mulch for apple trees has not previously been studied in well laid out experimental designs, if it has been studied carefully at all. Reports from orchardists who occasionally have used sawdust are indicative of favorable results, but in these cases no direct comparison has been made with other treatments. From the data presented in this paper it is evident that the trees did better when mulched with sawdust than when grown under ordinary sod culture, but not as well as when they were mulched with hay or with seaweed.

Beginning with the spring of 1947, one-half the number of trees in this experiment will receive annual applications of nitrogenous fertilizer.

## SUMMARY AND CONCLUSIONS

<sup>^</sup>In the absence of fertilizer application, hay mulch provides nearly ideal conditions for tree development and performance; seaweed takes second place. Sawdust mulch provides excellent conditions of soil moisture, but yield and tree growth are cut down, and the foliage is pale in color.

< Sod culture without additional mulch provides the least satisfactory condition as reflected in the very low yield of trees grown by this system, and in the failure of these trees to produce many fruit buds. —

The difference in moisture supply, organic matter and quantity of available nutrients in the soil, and weed control with the different treatments would account in large measure for the difference in response of McIntosh apple trees to hay, sawdust, and seaweed mulches and to sod culture.

Little or no difference was noted in the effect of the different treatments on fruit color and size except that seaweed mulch caused the development of darker ground color and less red color on fruit than did the other treatments. Fruit on trees mulched with seaweed usually matured later than fruit on other trees. Foliage color was much better with hay and seaweed mulch than with sawdust mulch or sod culture. Annual length growth of shoots was greatest in the case of the trees mulched with hay.

Hay mulch resulted in an accumulation of available nitrate, phosphorus, magnesium and potassium in the soil. Such accumulation was not found with sawdust and sod, but phosphorus did accumulate under seaweed. The pH of the soil and the amount of available calcium present did not differ among the different methods of soil management.

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## A Comparison of Various Methods for Reducing Transpiration Losses in Apples

By M. L. McMAHON, *Cornell University, Ithaca, N. Y.*

THE control of transpiration losses from fruit in storage is an important phase in the extension of storage life.

Some work has been done on this problem in recent years (1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14) employing various wax emulsions, plastic materials, wrappers and box liners but there is little information available as to the comparative effectiveness of these materials. This study was therefore designed to determine the relative merits of the several types of materials generally used to test the efficiency of various new materials arising from the prepackaging boom.

### METHODS

Duplicated lots of 10, uniform, mature Golden Delicious apples were used for each test. Twenty pound boxes were filled with untreated Golden Delicious apples except for the top layer. The 10 treated experimental fruits were placed in these boxes. An exception to this general practice was with the commercial liner and wrapper, here a standard bushel box was employed with 20 test fruits instead of 10.

The fruits were held for a short period in ordinary cold storage before treatment in 1945, and were then placed in storage at 33 degrees F. In the 1946 tests the fruits were picked and brought directly from the orchard, held 1 day in ordinary storage, treated, and stored at 33 degrees F. The average relative humidities during the 1945 and 1946 storage periods were 86 per cent and 85 per cent respectively.

Before treatment each lot of 10 fruits was weighed to the nearest gram. The weights of these duplicate apple units were roughly

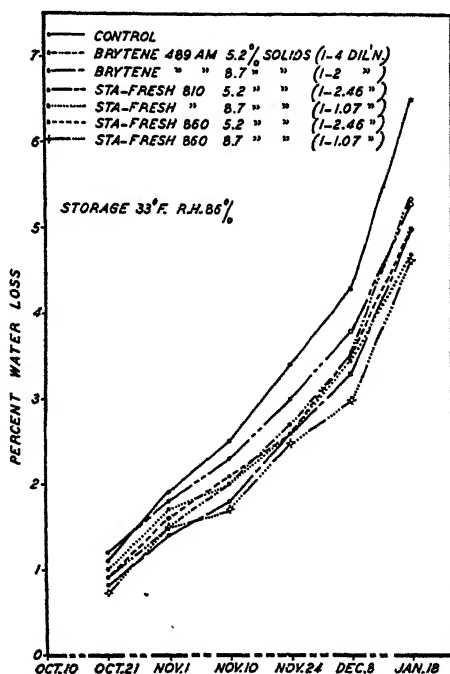


FIG. 1. Effect of various wax emulsions on weight loss from Golden Delicious apples during 14 weeks storage at 33 degrees F and 86 per cent relative humidity (1945).



within 5 per cent of each other, so that surface area would be more nearly constant (3).

"Loose wrap" means that the corners of the fruit wrappers were not twisted together. "Tight wrap" means that the corners were twisted together. "Heat stretched" Pliofilm means that a sheet of Pliofilm was warmed over a bunsen flame until easily stretched. Then an apple was quickly placed in the middle of the sheet and the film stretched over the apple and the corners twisted and heat sealed together. "Open corner" means that the sides and ends of the liner did not overlap at the corners. "Closed corner," means that there was a definite overlap at the corners and moreover the joints were sealed with a pressure tape. With all except the commercial type box liners, sufficient material was used so that when the sides and ends were folded over, four thicknesses covered the top layer of fruit.

### RESULTS 1945

*Waxes:*—In 1945 several dilutions of Brytene 489 AM, Sta-fresh 810 and Sta-fresh 860 were compared. Fig. 1 indicates that none of the differences between the waxes was very great and that moisture loss was on the whole rather high. Stronger concentrations were more efficient in reducing weight losses.

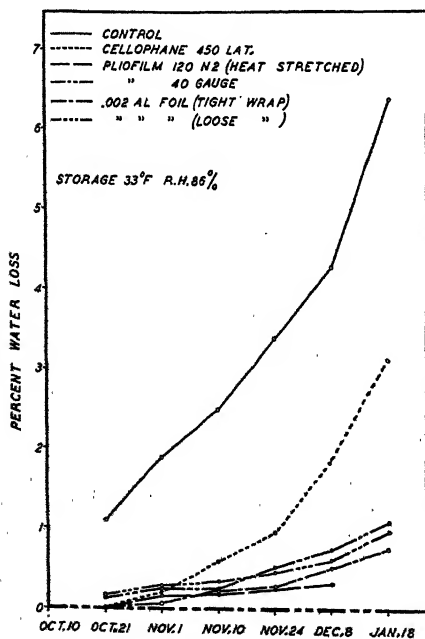


FIG. 2. The effect of various fruit wrappers on weight loss from Golden Delicious apples during 12 weeks storage at 33 degrees F, and 86 per cent relative humidity (1945).

*Wrappers:*—Fig. 2 presents the results with wrappers and when compared with Fig. 1 indicate that the wrappers are much more effective than the waxes. Heat stretched Pliofilm<sup>1</sup> was apparently the most efficient, followed by aluminum foil, pliofilm 40 gauge wrap and finally Cellophane.

*Box Liners:*—Since box liners require approximately one-fifteenth as much material as individual wrappers (13), this is a most economical method of employing moisture loss prevention materials. Fig. 3 indicates that aluminum liners give good control of weight loss. They were far superior to waxes but not as efficient as the wrappers tested (with the exception of Cellophane).

<sup>1</sup>Moisture loss weighings were terminated with this treatment 8 weeks before the others owing to loss of one of the samples.

TABLE I—THE COMPARATIVE EFFECT OF ALL MATERIALS TESTED 1945 ON GOLDEN DELICIOUS APPLES AFTER 14 WEEKS AT 33 DEGREES F, AND 86 PER CENT AVERAGE RELATIVE HUMIDITY

Treatment	Water Loss (Per Cent)	Reduction in Water Loss Compared to Losses in Control (Per Cent)	Firmness (Pounds)	Soluble Solids (Per Cent)	Ground Color	Remarks
Pliofilm 120N2 (heat stretched)*.....	0.43	93	14.7	15.3	3.0	Very good condition
.002 inch aluminum foil (tight wrap).....	0.72	89	13.2	15.7	4.0	Excellent
.002 inch aluminum foil (loose wrap).....	0.99	84	13.9	16.5	4.0	Excellent
.002 inch aluminum foil (closed corner).....	1.1	83	14.6	16.1	4.0	Very good condition
Pliofilm 40 gauge wrap.....	1.1	83	14.8	16.1	3.9	Good condition
Average values.....	—	—	14.3	16.0	3.9	
.002 inch aluminum foil on 40 pound Kraft liner (closed corner).....	2.0	69	14.7	15.5	3.9	Diphenyl odor, otherwise good
.002 inch aluminum foil on 40 pound Kraft liner (open corner).....	2.7	58	14.4	16.2	4.0	Very good condition
.002 inch aluminum foil liner (open corner).....	3.0	53	14.6	16.2	4.0	Good condition
Cellophane 450 Lat. Wrapper.....	3.1	52	14.3	16.8	4.0	Very good condition
Average values.....	—	—	14.5	16.2	4.0	
Sta-fresh 860 (8.7 per cent solids).....	4.6	28	15.2	17.0	4.0	Good condition
Sta-fresh 810 (8.7 per cent solids).....	4.7	27	15.0	17.0	3.8	Very slight shrivel, good flavor
Brytene 489 AM (8.7 per cent solids)...	4.7	27	15.8	16.5	4.0	Slight shrivel, spongy
Sta-fresh 860 (5.2 per cent solids).....	5.0	22	14.1	15.8	4.0	Slight shrivel, mealy
Sta-fresh 810 (5.2 per cent solids).....	5.3	17	14.5	17.1	4.0	Slight shrivel, good flavor
Brytene 489 AM (5.2 per cent solids)....	5.4	16	14.7	16.5	4.0	Slight shrivel, fair
Average values.....	—	—	14.9	16.5	3.98	
Control.....	6.4	—	15.9	17.5	4.0	Spongy, fair to poor condition

\*The figures presented for Pliofilm heat stretched were taken after 6 weeks when this treatment was terminated owing to loss of one of the samples.

#### DISCUSSION OF COMPARATIVE EFFECTIVENESS OF MATERIALS TESTED 1945

Table I summarizes the results of the main experiment. At 33 degrees F it is noticeable that the materials fall into distinct groups with respect to their efficiency in controlling moisture loss.

The most efficient group is made up almost entirely of wrappers and includes all those tested (with the exception of Cellophane). The second best group is composed of aluminum foil box liners and the Cellophane wrap and the third is made up entirely of waxes.

The relative efficiency of the materials in percentage is indicated in column 3, Table I.

Pressure test data are subject to the error that comes with increasing sponginess of the fruit as it loses water.

Soluble solids were higher with greater water loss. This is probably due to concentration of sugars in the less efficient packages.

No very definite ground color trend is evident. The results as a whole indicate that of all the wrappers Pliofilm (heat stretched) showed the most promise followed by the aluminum foils and Pliofilm (40 gauge).

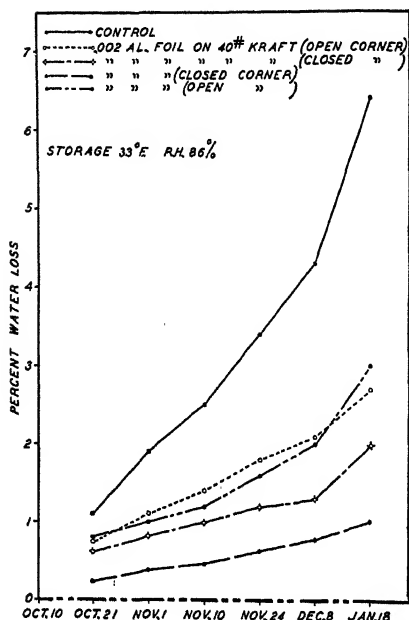


FIG. 3. Effect of aluminum foil box liners on weight losses in Golden Delicious apples during 12 weeks storage at 33 degrees F, and 86 per cent relative humidity (1945).

Aluminum foil while very efficient as a wrapper is highly impractical as such, at least in such heavy gauges. This material shows real promise as a box liner. There is an indication that such a liner should have closed corners for maximum efficiency.

Cellophane has merit as a wrapper but is poorer than the box liners tested.

The waxes were the poorest of all materials tested. Within the wax group Brytene 489 AM was the poorest. There was no very marked difference between Sta-fresh 810 and 860.

It is important to note that while some fruits were more palatable than others at the conclusion of the season, no off flavors were obtained with any treatment.

## RESULTS 1946

This season several of the more promising new Cellophane materials were tested as box liners along with aluminum foils. These liners were all made in the laboratory from supplies of the materials in rolls. Results are presented graphically in Fig. 4.

The data clearly show that a closed corner liner was superior to an open corner type. However, the differences between them are not commercially significant.

It is evident that Lumarith is widely separated from the other materials and is the poorest of the liner materials tested.

Plain aluminum foil (that is, foil with no paper backing) was most efficient. It should be noted that a highly objectionable strong diphenyl odor present on Kraft backed aluminum foil used in 1945 was eliminated by the manufacturer in 1946 thus preventing fruit flavor contamination.

Table II gives the result of a test made with a commercial light gauge aluminum foil box liner and wrapper. This treatment was set up under the same conditions as the rest of the experiment, but a few days later and with a later picked lot of fruit. It is evident that such a light weight foil gives excellent control over moisture loss indicating that heavier gauges are unnecessary for this purpose. However, it must be remembered that the lighter materials are more subject to puncturing and tearing.

## COMPARATIVE EFFECTIVENESS OF MATERIALS TESTED 1946

Table III summarizes the results of the main experiment. These data clearly indicate that a closed corner box was best, that plain aluminum foil was superior to Kraft backed foil and to all other liners tested and that Lumarith was the poorest of all as a moisture loss control agent.

Two waxes were checked this year with Pliofilm 40 gauge wrap and were found to be much poorer than the latter.

All fruits were in good condition except in two cases (see Table III) where the rating was fair. No off flavors were encountered.

## SUMMARY

In this study a general survey was made of the relative effectiveness of the main types of moisture loss control agents used with apples. It is obvious that from the multitude of commercial materials available only a select few from each group could be subjected to investigation. Therefore it must be pointed out that the conclusions enumerated below are of necessity limited to the specific materials tested.

1. The wax emulsions used were the least effective of any group of materials tested.

2. Stronger concentrations of solids in waxes, within the range examined increased their efficiency.

3. Heat stretched Pliofilm was the most effective wrapper. It was followed closely by .002 inch aluminum foil and a "40 gauge" Pliofilm wrap.

4. .002 inch aluminum foil was considered impractical as a wrapper owing to its heavy gauge. However, .00035 inch foil proved to be a very effective substitute.

5. A box liner with lapped, sealed coners was more effective than

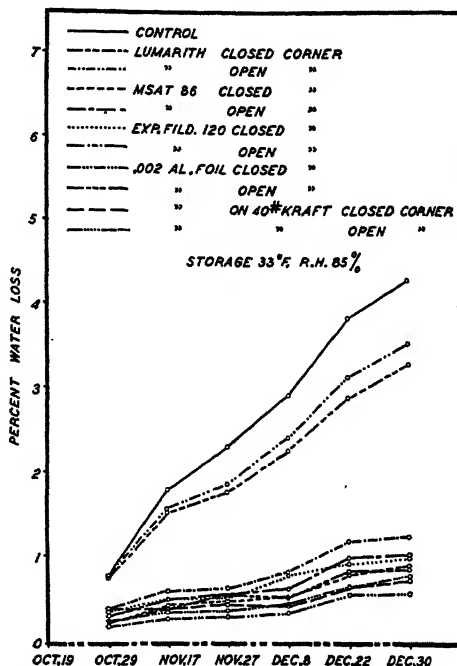


FIG. 4. Effect of Lumarith, various Cellophanes, and aluminum foil box liners on weight losses from Golden Delicious apples during 10 weeks of storage at 33 degrees F and 85 per cent relative humidity (1946).

TABLE II—EFFECT OF A "COMMERCIAL" .00035 INCH THICK ALUMINUM FOIL BOX LINER AND WRAPPER ON GOLDEN DELICIOUS APPLES AFTER 9 WEEKS AT 33 DEGREES F, AND 85 PER CENT RELATIVE HUMIDITY

Treatment	Water Loss (Per Cent)	Reduction in Water Loss (Compared to Losses in Control) (Per Cent)
Control.....	5.15	—
.00035 inch 2S-O alloy aluminum foil liner.....	1.0	81
.00035 inch 2S-O alloy aluminum foil wrapper.....	0.5	90

an open corner box. The difference, however, was not commercially significant.

6. .002 inch aluminum foil was the best box liner material tested if the corners were sealed.

7. If the corners were "open" then aluminum foil with a Kraft backing was found to be the superior liner.

TABLE III—COMPARATIVE EFFECT OF MATERIALS TESTED 1946 ON GOLDEN DELICIOUS AFTER 10 WEEKS AT 33 DEGREES F, 85 PER CENT RELATIVE HUMIDITY

Treatment	Water Loss (Per Cent)	Reduction in Water Loss Compared to Losses in Control (Per Cent)	Firmness (Pounds)	Soluble Solids (Per Cent)	Ground Color	Remarks
.002 inch aluminum foil liner (closed corner)	0.57	87	9.8	10.3	2.5	Slight sweating, good condition
.002 inch aluminum foil on 40 pound Kraft liner (closed corner)	0.74	83	9.8	10.1	2.5	Slight sweating, good condition
Phiofilm 40 gauge wrapper.....	0.75	83	10.7	10.8	2.7	Good condition
.002 inch aluminum foil on 40 pound Kraft liner (open corner)	0.77	82	9.9	10.3	2.4	Good condition
300 MSAT86 Cellophane liner (closed corner)	0.91	79	10.4	10.5	2.6	Slight sweating, good condition
300 Exp. Fild. No. 120 Cellophane liner (closed corner)	0.94	77	10.2	8.4	2.7	Heavy sweating, flat taste good condition
300 MSAT86 Cellophane liner (open corner)	1.15	73	9.8	10.3	2.5	Heavy sweating, good condition
300 Exp. Fild. No. 120 Cellophane liner (open corner)	1.25	71	9.9	10.9	2.5	Heavy sweating, good condition
Average values	—	—	10.0	10.2	2.6	
Lumarith liner (closed corner).....	3.3	23	10.0	10.4	2.7	Good condition
Sta-fresh 860 (9 per cent solids).....	3.35	22	10.2	10.5	2.7	Good condition
Lumarith liner (open corner).....	3.55	17	9.7	10.5	2.6	Good condition
Sta-fresh 860 (6 per cent solids).....	4.0	7	10.0	10.8	2.6	Fair condition, a little spongy
Average values	—	—	10.0	10.6	2.7	
Control	4.3	—	11.2	10.4	2.7	Good condition, slight shrivelling

8. A "light" (.00035 inch) gauge aluminum foil was found to be as effective as a heavy (.002 inch) gauge in controlling moisture losses.

9. Little difference of commercial significance was found between the various Cellophanes tested.

10. Lumarith was found to be a very brittle, easily cracked material and was only slightly more effective than wax emulsions.

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# Further Studies on Sprays Containing 2,4-Dichlorophenoxyacetic Acid, and Some Related Compounds, for Reducing Harvest Drop of Apple

By C. P. HARLEY, H. H. MOON, and L. O. REGEIMBAL,<sup>1</sup>  
*U. S. Plant Industry Station, Beltsville, Md.*

FROM experiments conducted in 1945 it was reported (2, 3) that sprays containing 10 parts per million of 2,4-dichlorophenoxyacetic acid were highly effective in reducing fruit drop of Winesap and Stayman Winesap apple, and that the period of effectiveness extended over a relatively long time. Some other varieties, including Oldenburg, McIntosh, Delicious, York Imperial, and Golden Delicious, failed to show response to this chemical.

Studies were continued in 1946 to obtain additional information on the apparent varietal selectivity of 2,4-D and the response of certain varieties to other closely related compounds.

## MATERIALS USED

2,4-dichlorophenoxyacetic acid (hereinafter written 2,4-D acid) crystals were dissolved in a small quantity of ethyl alcohol and added directly into the spray tank, pouring the material slowly into the water while the agitator was running.

Sodium 2,4-dichlorophenoxyacetate (sodium salt) and ammonium 2,4-dichlorophenoxyacetate (ammonium salt) were first dissolved in a small amount of water and added to the tank as described above.

Butyl 2,4-dichlorophenoxyacetate (butyl ester) was dissolved in a light miscible oil.

Triethanolamine 2,4-dichlorophenoxy acetate (triethanolamine salt) was formulated by dissolving 2,4-D acid in a slight excess of triethanolamine and warming gently.

Weedone, a commercial weed killer, purchased July 1945 in Washington, D. C.

Bordeaux mixture (2-4-100) was prepared in the spray tank, and 2,4-D acid, dissolved in alcohol, was added after thorough mixing and during agitation.

Carbowax 1500 was liquefied by heat and dissolved in water.

## RESULTS

Experiments on varietal selectivity, conducted on Williams, Oldenburg, McIntosh, Summer Rambo, Jonathan, Rome Beauty, York Imperial, and Arkansas (Black Twig), resulted generally in negative response to 2,4-D acid and the salts and esters. Sprays with concentrations as high as 50 parts per million applied to McIntosh,

<sup>1</sup>Senior Physiologist, Associate Pomologist, and Associate Plant Physiologist, respectively, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

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Summer Rambo, and York Impérial were ineffective in significantly reducing fruit drop. With 10 and 50 parts per million of 2,4-D acid and with the same concentrations of the sodium salt there was a slight reduction in drop of McIntosh up to September 5, but beyond this date the drop approached that of the unsprayed. One plot of Jonathan sprayed with 10 parts per million of 2,4-D acid showed a significant reduction in drop; however, owing to the limited number of trees involved, and since none of the esters and salts followed a similar pattern, this variety probably cannot at this time be considered as responsive.

The apparent highly selective action of 2,4-D acid and related compounds was further emphasized in the experiment with the Arkansas. Although generally considered to be a seedling of Winesap, convincing evidence obtained this year showed that none of the 2,4-D sprays reduced harvest drop of this variety. Ninety Arkansas trees were included in this test.

*Stayman Winesap*.—The relatively long period of effectiveness of 2,4-D on responsive varieties has been pointed out (1, 2, 3). Sprays applied during the summer of 1946 to Stayman Winesap trees further confirm these observations. In Table I the accumulated percentage of drop for trees sprayed on July 24 indicates good effectiveness when applied at this very early date. Similar trees sprayed August 23, however, dropped less than one-half as many apples as those sprayed July 24. The normal harvest date in this orchard would have occurred between October 9 and October 16, and during this period good practical drop prevention was obtained with either spray, although July 24 was apparently too early for the most efficient results. This experiment was not concluded until the unsprayed trees had dropped practically all fruits, and yet there was no indication that the hormonal effect had "run out" on those receiving the spray.

TABLE I—RELATION BETWEEN TIME OF 2,4-D SPRAY APPLICATION AND FRUIT DROP REDUCTION ON STAYMAN WINESAP TREES

Treatment	Date Spray Applied	Concentration (Ppm)	Accumulated Percentage of Fruit Drop							
			Sep 13	Sep 26	Oct 2	Oct 9	Oct 16	Oct 23	Oct 25	Nov 5
2,4-D acid...	July 24	10	0.5	2.3	7.0	9.8	13.9	18.9	23.1	42.8
2,4-D acid...	Aug 23	10	0.1	0.4	3.4	3.9	5.9	7.4	8.9	21.1
Unsprayed...		—	2.2	5.9	11.3	19.0	41.8	69.7	78.6	94.9

To determine the value of compounds closely related to 2,4-D acid as sprays to reduce harvest fruit drop, 95 Stayman Winesap trees were selected and divided into eight plots of 10 trees each, with the remaining 15 trees as unsprayed controls. The first spray application was made August 29. One hour after the spraying was completed, about .5-inch of rain fell. In order to evaluate the possibility of reduced intensity by the rain, another application of spray was made September 11 on five trees of each treatment, with the exception of the sodium salt. The average accumulated percentages of drop for trees receiving only one spraying and for trees receiving the repeat



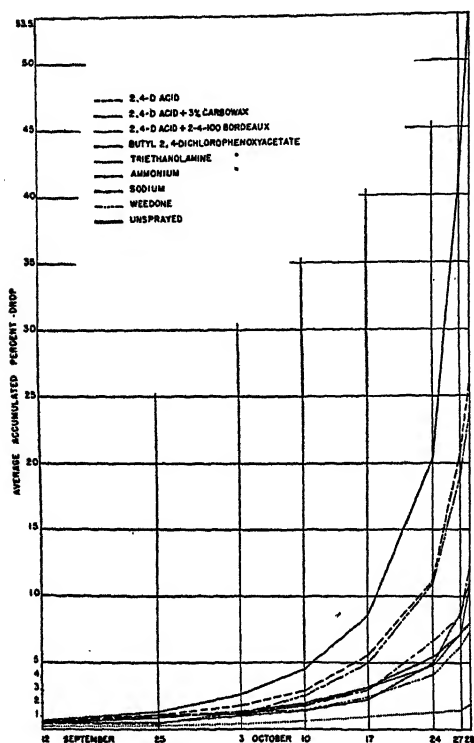


FIG. 1. Average accumulated percentages of fruit drop for Stayman Winesap trees sprayed with 10 parts per million solutions of 2,4-D compounds on August 29, one hour before a heavy rain.

application are shown in Fig. 1 and Fig. 2, respectively. These curves indicate: (a) The heavy rain following spray application reduced the intensity of all compounds except the butyl ester. Evidence obtained in other experiments precludes the possibility of other influences, such as time of application and doubled concentration, as being operative in the greater intensity of the repeat application. The most severe reduction in efficiency by rain occurred in plots sprayed with 2,4-D acid and those receiving 2,4-D acid plus 2-4-100 bordeaux mixture. (b) All compounds used in this test were highly effective in reducing fruit drop of Stayman Winesap. The lowest intensity was found where 2,4-D was combined with bordeaux mixture, and the highest intensity of all com-

pounds was that of the butyl ester. In fact, the butyl ester spray reduced drop to a greater degree than any material yet tested in our experiments. On the basis of intensity alone, however, the butyl ester cannot be recommended for commercial orchard spraying at this time, for it was noted at harvest that the fruit on trees sprayed with this compound showed a pronounced advance in maturity. The average pressure test of apples from trees sprayed with butyl ester was 13.3 pounds, as compared with 14.7 pounds for the unsprayed fruits. Also water core was present in 50 per cent of the fruits sprayed with the butyl ester, in contrast to none in the unsprayed. Advanced fruit maturity was not observed in any of the other plots.

The relatively long period of effectiveness of 2,4-D in reducing fruit drop of Stayman Winesap and Winesap varieties offers the possibility of incorporating this growth substance with late summer fungicidal and insecticidal sprays. A combination of 10 parts per million of 2,4-D acid and bordeaux mixture 2-4-100 was used to spray a Stayman Winesap orchard July 29. The results of this treat-

ment are graphically shown in Fig. 3. Although the data do not evidence the intensity of effect generally obtained with 2,4-D, this can be accounted for by an analysis of existing evidence and an explanation of circumstances attending the experiment. In addition to a possible reduction of intensity by the bordeaux and the early date of spray application, a very severe windstorm occurred on October 12, having an average wind velocity of about 30 miles per hour for a period of 6 hours and attaining estimated velocities of 50 miles per hour at frequent intervals. Under these conditions the spray prevented the drop of an average of 8.8 bushels per tree, with an average total crop of 32 bushels per tree.

#### LABORATORY TEST TO EVALUATE VARIETAL RESPONSE TO 2,4-D ACID

The highly selective action of 2,4-D compounds in delaying fruit abscission for certain varieties of apples and not for others suggests the possibility that other untried growth-regulating substances may exert a similar influence on varieties that have shown little or no response either to naphthaleneacetic acid or to 2,4-D sprays. A simple technique that would give a quick test of these substances would contribute materially to reducing the time and the cost required for orchard trials.

Late in the summer of 1946, some preliminary studies were made on varietal response to 2,4-D acid by treating cut petioles of terminal shoots with the growth substance. The terminal shoots were cut from the tree and placed in water containers in the laboratory. Leaves were removed by cutting through the petioles, leaving about 12 millimeters of the stub attached to the shoot. Two terminal leaves were not removed. One half of the shoots received 2,4-D acid either by spraying a water solution of 10 parts per million concentration on the

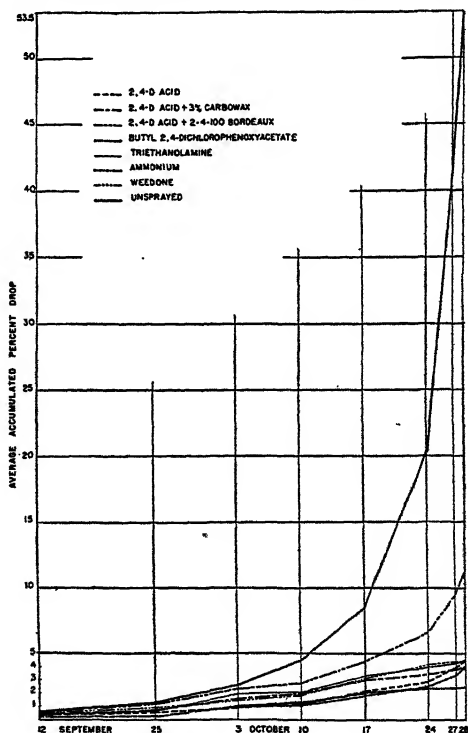


FIG. 2. Average accumulated percentages of fruit drop for Stayman Winesap trees sprayed with 10 parts per million solutions of 2,4-D compounds on August 29 one hour before a heavy rain, followed by another application September 11.

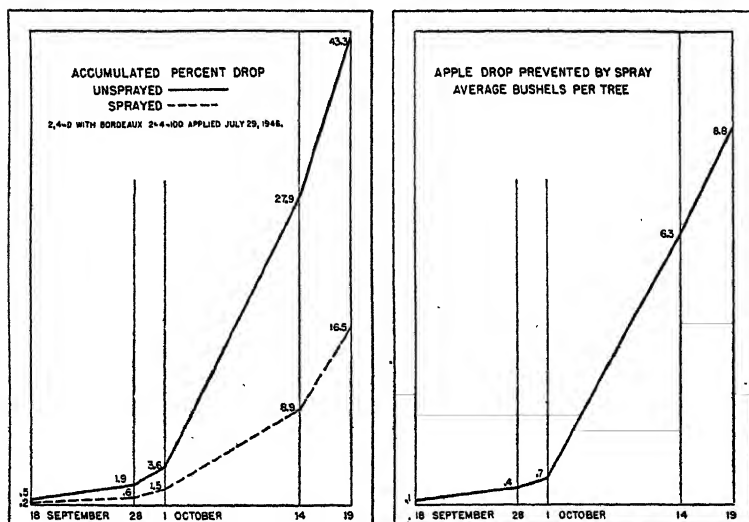


FIG. 3. Accumulated percentage of fruit drop and the average number of bushels of apples prevented from dropping from Stayman Winesap trees sprayed with 10 parts per million solutions of 2,4-D acid in bordeaux mixture 2-4-100. Spray applied July 29, 1946.

cut surface of the petioles or by placing a drop thereon. The remaining shoots were untreated. Records were taken on the time required for the cut petioles to abscise.

The first samples were collected September 18 and consisted of terminal shoots, approximately 35 centimeters in length, of Stayman Winesap, York Imperial, and Rome Beauty. Eight days later abscission of petioles began on all control and 2,4-D-treated shoots of York Imperial and Rome Beauty, and abscission was complete on October 7. Petioles of Stayman Winesap treated with the 2,4-D acid, on the other hand, remained green and firmly attached for 101 days.

Fig. 4 illustrates the condition of these shoots at the end of 101 days in the laboratory.

Another experiment, including the varieties Rome Beauty, Delicious, Winesap, Stayman Winesap, Golden Delicious, York Imperial, and McIntosh, was initiated October 8. Total abscission had occurred on all controls and all 2,4-D-treated varieties except Winesap and Stayman Winesap by November 4, or 27 days after the experiment was started. Petioles remained firmly attached to 2,4-D-treated Stayman Winesap and Winesap shoots for 63 days. A higher intensity of effect on these two reactive varieties would probably have resulted if samples had been taken earlier in the season.

The responses to 2,4-D acid obtained by this laboratory method with petioles were identical with those from orchard spraying to prevent fruit drop of these same varieties; and, while further studies are necessary, this method of evaluation offers promise of being helpful in future work on varietal response to growth substances.

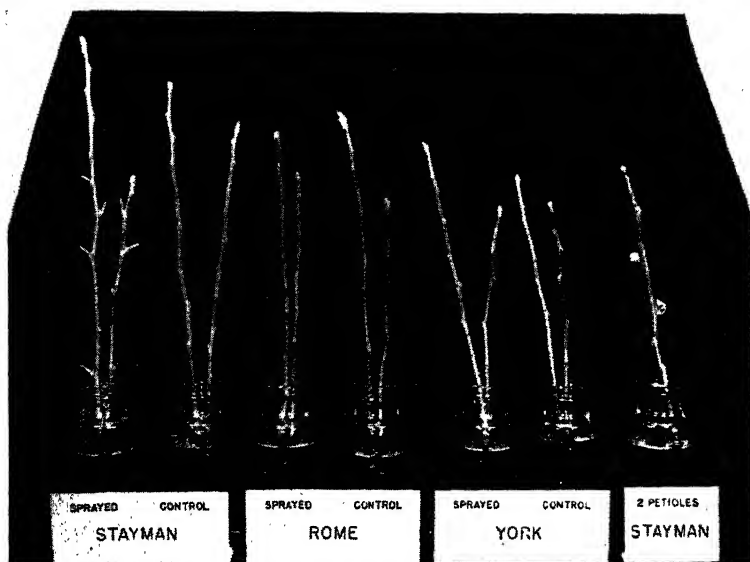


Fig. 4. Effect of spraying 10 parts per million solutions of 2,4-D on cut petioles of Stayman Winesap, a reactive variety, and Rome Beauty and York Imperial, nonreactive varieties. Stayman Winesap shoot at right had two petioles treated with cotton saturated with a 10 parts per million solution of 2,4-D acid. Note abscission of petioles above and below the two receiving 2,4-D acid. Photographed 101 days after treatment.

#### SUMMARY

Preharvest sprays containing 10 parts per million of 2,4-dichlorophenoxyacetic acid have for two consecutive years shown high intensity and a long period of effectiveness in reducing harvest drop of Stayman Winesap and Winesap apples.

Some salts and esters of 2,4-dichlorophenoxyacetic acid were highly effective in reducing fruit drop. The butyl ester showed the highest intensity, but this compound caused serious advance in fruit maturity at harvest.

The intensity of most 2,4-D compounds was reduced significantly when a heavy rain occurred about 1 hour after the sprays were applied.

Combined with a late-summer bordeaux spray, the effectiveness of 2,4-D acid was apparently somewhat reduced, although this spray prevented the drop of 8.8 bushels per tree on trees bearing a total crop of 32 bushels per tree, in comparison with similar unsprayed trees.

A laboratory test to evaluate varietal response to 2,4-D acid is described.

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# Chromosome Numbers of Apple Varieties and Sports<sup>1</sup>

By JOHN EINSET and BARBARA IMHOFE, *New York State  
Agricultural Experiment Station, Geneva, N. Y.*

To determine if they might be polyploids, cytological studies have been made of apple varieties not previously reported in the literature, of varieties in certain instances where discrepancies have occurred in reports of their chromosome numbers, and of sports of varieties, especially large-fruited ones.

## METHODS

Apples are poor cytological material, the chromosomes are small, meiotic stages are not easily located, and preparations are rather difficult to interpret. For this reason somatic mitoses in buds were studied instead of meiotic figures. Branches were collected in late February and early March and placed in water in a heated greenhouse. After 2 to 5 days in the greenhouse leaf or flower buds were fixed in CRAF (13). Care was taken to remove the bud scales, the outer leaves, most of the hairs, and the woody tissue attached to the bud. The trimmed bud was then plunged into the fixing solution and the air exhausted with an aspirator. These precautions assured rapid penetration of the fixing agent. After imbedding and sectioning, the material was bleached and stained in Crystal Violet. Good somatic mitoses were most abundant in young leaves and in developing flower parts, especially in anther and ovary walls.

## MATERIALS

The materials for the present study were collected from the Agricultural Experiment Station orchards in Geneva, New York, with only a few exceptions as indicated in Table I. The locations of the trees from which materials were taken are given in the table; the figures indicate orchard, row and tree number respectively. It seems highly important that the exact source of cytological material should be given in order that the same individual may be referred to in the future if the occasion should arise. In this way we have a living herbarium of the plants studied.

## OBSERVATIONS

In Table I the varieties are grouped according to their chromosome number; first, the diploids with 34 chromosomes in somatic cells; second, the triploids with 51 chromosomes; and third, a number of periclinal chimeras made up of diploid and tetraploid parts. The present location of each variety and the original source of trees or scions, including the year of original accession, is given. Some minor notes are also included in the table. Those cases which merit further discussion will now be considered.

*Pollen Germination*.—A number of apples were examined that had

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## Variety

Anoka  
 Beacon (Minn. No. 423)  
 Bedford Red  
 Belle sans Fespin  
 Black Gilliflower  
 Blue Pearmain  
 Boiken  
 Carlton  
 Champagner Reinette  
 Chenango  
 Crimson Beauty  
 Davenport No. 25  
 Erickson  
 Giant Red Rome  
 Granny Smith  
 Haralson  
 Hardanger Rosenstrips  
 Hubbardston  
 Jumbo  
 Kaiser Wilhelm  
 Kaupanger  
 Kosztela  
 Lady  
 Lawfam  
 Lobo  
 Melba  
 Midttun  
 Oliver  
 Orenco  
 Perkins  
 Prairie Spy (Minn. No. 1007)  
 Pumpkin Sweet  
 Red Duchess  
 Redhook  
 Rondestveit  
 Scarlet Beauty

Star  
 Stearns  
 Sturmer Pippin  
 Sutton  
 Torstein

Bietigheimer  
 Blaxtayman  
 Close (U.S.D.A. No. 57)  
 Fall Pippin  
 Graue Herbst Reinette

Hibernial  
 Regmalard  
 Red Ribston  
 Stark  
 Red Stark  
 Red Stark  
 Miami  
 No. 179  
 No. 382  
 No. 372  
 No. 257 Revert  
 Smokehouse  
 Turley  
 Washington Strawberry

Jonathan Sport  
 "Giant" Rome  
 "Giant" Spy  
 "Large" Wealthy





shown, in tests in 1936, the poor pollen germination characteristic of triploids. Blue Pearmain, Chenango and Sutton were found to be diploids with 34 chromosomes in somatic cells. Regmalard, Turley and Washington Strawberry were triploids with 51 chromosomes.

*Turley*:—It is worthy of note that Turley, in addition to Arkansas and Stayman Winesap, is a triploid. These three varieties are all thought to be seedlings of Winesap, a diploid parent. It is unlikely that triploids should occur with an unusually high frequency in seedlings of Winesap and yet three such seedlings have been selected and propagated as varieties. No diploid seedlings of Winesap have to our knowledge become commercial varieties.

*Close*:—This triploid apple is an early variety ripening with or slightly ahead of Yellow Transparent. Most triploid apples ripen late and have good storage qualities (7).

*Hibernal*:—The material was kindly supplied by T. J. Maney of Iowa State College in 1944. Professor Maney wrote that the variety was found to be triploid in work done at Iowa. This report is merely a confirmation of that work.

*Stark*:—Roscoe (14) reported that Stark was triploid with  $51\frac{1}{2}$  chromosomes from meiotic counts. Newcomer (12) studied four strains of Stark including: 1. "Normal" Stark; 2, No. 382, a red-fruited sport; 3. No. 179, another red-fruited sport; and 4. No. 287, a russeted sport. These four strains were each reported to have a chromosome number of 42, or 21 pairs as determined from metaphase and anaphase stages of meiosis. No observations were made of somatic mitoses. Swanson and Gardner (16) made a study of one of these sports, No. 287 (the russeted form), branches of this sport that reverted to the original Stark type, and branches of "Normal" Stark. In their study the smear technique was used and meiotic chromosomes were studied for the most part. Stark and several additional strains of Stark examined were found to have 42 chromosomes in agreement with Newcomer (12). However, the russeted sport (No. 287) was found to have a complement of 51 chromosomes as determined at metaphase I and anaphase I of meiosis. This is not in agreement with Newcomer's report for this sport. A single branch showing a complete reversion to the parental type had 42 chromosomes. Branches showing partial reversion had 51 chromosomes except one which had reverted more decidedly in the direction of the original Stark. This branch had a somatic complement of 46 chromosomes in cells of the tapetum (16, Figure 5D).

Chromosome counts of a number of strains of Stark have been made (Table I) and in all cases the somatic chromosome number was determined to be 51, in agreement with Roscoe (14), but not in agreement with the other workers cited. Chromosome counts were made of Stark originally accessioned in 1888 and of three red-fruited sports of Stark from different sources (Fig. 1, A and B). In addition, chromosome counts were made in a number of the sports studied at Michigan and kindly sent to this Station in 1945 by Director V. R. Gardner. The red sports Nos. 179 and 382, reported by Newcomer to have 42 chromosomes, were found to have 51 chromosomes in the

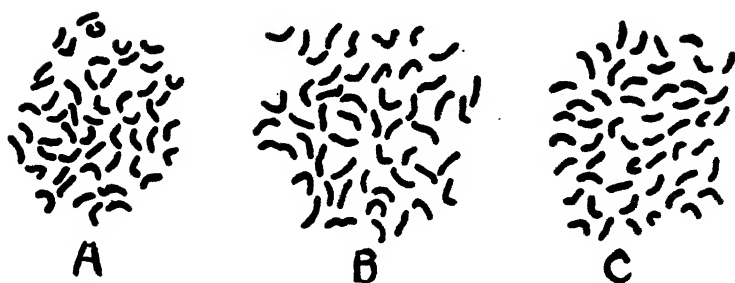


FIG. 1. A, Red Stark, 17-8-18, somatic metaphase from anther wall. B, Miami (Red Stark), metaphase from leaf parenchyma. C, Stark No. 379, metaphase from leaf parenchyma.  $\times$  c. 3300.

material examined. Another red sport, No. 372, was also found to have 51 chromosomes (Fig. 1, C). Buds from scion wood labelled No. 287 Revert, reported to have 42 chromosomes (16) proved upon examination to have 51 chromosomes.

The disagreement in reports of chromosome number in strains of the Stark apple is most confusing. Newcomer (12) suggested that errors due to technique and interpretation may possibly account for some of the discrepancies in various reports dealing with apples. Certainly meiotic stages are most difficult to interpret in the material. We would also suggest that somatic stages may be difficult. If the somatic metaphase from tapetal tissue in Fig. 5D of Swanson and Gardner's paper is studied and compared with our Fig. 1, it will be seen that in several instances the chromosomes are out of proportion in length. They could easily be interpreted to be two chromosomes, with adjacent or overlapping ends. From the illustration and with this fact in mind the figure could be interpreted as having 51 chromosomes instead of 46.

*Chimeras*.—A number of large-fruited sports of different apple varieties have been examined cytologically. Four of these sports have been found to be periclinal chimeras with one or more layers of diploid cells covering a tetraploid central portion in the stem apex.

*"Giant" Spy*.—In this sport the stem apex consists of a two-layered surface of diploid cells covering a tetraploid central portion. The pith and most (perhaps all) of the vascular tissue of the stem is tetraploid. The anthers and ovules develop from the diploid cell layers and consequently this form acts like a diploid in its breeding behavior (4). A study of the leaf development in Giant Spy has been initiated (1). The petiole is largely tetraploid. The diploid portion of the "cortical area" varies from 2 to 10 cells in width. The stipules contain tetraploid veins but surrounding parenchyma is diploid. In the blade all principal veins and many smaller veins have been identified as tetraploid. The parenchyma and epidermis are diploid.

*"Large" Wealthy*.—Six leaf buds of this sport have been studied. Several hundred cells in which chromosome counts could be made have been examined. Cells with the diploid number of chromosomes have been found only in the epidermal layer of the stem apex, petioles,

stipules and leaves. In every instance where a dividing cell has been observed in a tissue other than the epidermis, this cell has been tetraploid. Apparently a single layer of diploid cells covers a tetraploid central portion in the stem apex. The breeding behavior of this sport has not yet been studied but it will probably behave like a tetraploid.

"*Giant*" *Rome*:—Only a limited number of observations have been made to date; two leaf buds and several flower buds have been examined. It is probable that three layers of diploid cells cover the tetraploid central portion in the stem apex. Tetraploid cells have been observed in the pith and in the vascular tissue of the stem, in vascular bundles at the base of petioles or leaves and occasionally in ovary walls.

*Jonathan Sport*:—Five leaf buds of this sport have been examined. There are probably two or more layers of diploid cells covering the tetraploid central portion in the stem apex. The pith is tetraploid and the vascular tissue of the stem is tetraploid. Tetraploid cells have been found in bundles leading into leaf bases and in the vascular tissue of the petioles. A layer of tetraploid parenchyma surrounds the veins in the petioles and apparently extends up into the leaves.

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## Histogenesis of Some Bud Sports and Variegations

By HAIG DERMEN, *U. S. Plant Industry Station, Beltsville, Md.*

RECENT studies on colchicine-induced forms of datura (8, 9, 10), cranberry (4, 5), and peach (unpublished) have brought out some facts that indicate the tissue complex that may be involved in such bud sports (somatic mutations) as color sports, giant fruit sports, and gross chlorophyll variegations. When colchicine was applied to the cranberry, various types of periclinal and sectorial—confined to one layer, or mericlinal, in the sense used by Jorgenson and Crane, (7)—cytochimeral branches resulted. Rarely were there found branches that were uniformly polyploidized throughout. The mechanism underlying such developments in cranberry has previously been described (4, 5), so that only such phases of that study as are considered to be pertinent to the present discussion will be referred to here.

The fact that colchicine treatment of plants has resulted in periclinal polyploid chimeras is evidence that probably growth of shoots in all angiosperms is never from either a single cell or a single group of terminal initial cells, but rather from a number of distinct cell layers at the very summit of the shoot apex.

In contrast, in some lower plants shoot growth is from a single terminal initial cell which is distinguishable by its large size and tetrahedral shape. In the root tips of such plants there is a similar terminal cell that gives rise outwardly to the root cap and inwardly to the root proper. It would appear that in such plants, since the whole growth is from a single cell, neither periclinal nor sectorial chimeras could develop. If a mutation did occur in the terminal cell of such a plant, its effect would involve the entire growth from that terminal cell.

In such gymnosperms as have been studied by conventional methods [Foster (6) and others] the shoot appears to develop from single cells or a group of cells at the shoot apex. Here there is apparently no formation of cells into distinct layers as in the angiosperms, on the basis that cell division at the summit of the shoot apex is at random in all planes. Therefore, in the gymnosperms also no periclinal chimeral forms should appear, though it would be possible for true sectorial chimeras to occur that would extend from the epidermis of the stem into the very center of the pith. Such chimeras would be similar to the sectorials induced by X-radiation in the roots of *Crepis capillaris* and *Vicia faba* by Brumfield (1), for in the roots the primary histogenic region is under the root cap. This region is comparable to layer III of the shoot apex in cranberry and other angiosperms, in which layer the cells divide at random in all planes. Chromosomal changes induced in the roots by X-radiation were found by Brumfield to occur in "wedge-shaped sectors, including root cap, epidermis, cortex, and central cylinder". Brumfield has suggested that "the whole root develops from but few cells, possibly three, at the extreme tip of the root". The sectorial nature of the induced chromosomal changes in the roots is explained thus: "Since chromosome aberrations induced by X-radiation apparently occur at random, it is highly improbable

that rearrangements involving similar lengths of the same chromosomes should occur in two adjacent cells". Fundamentally this concept concerning the mechanism involved in the development of the sectorial chimeral forms observed in the roots after irradiation is in agreement with the occurrence of mericlinal (a sectorial confined to one layer) forms in colchicine-treated cranberry plants. However, the results in cranberry showed (4) that there could not be a fixed number of *three* central cells in each layer, but that this number might be *one* or *two* as well as *three*. Therefore some irradiated roots should have shown certain chromosomal changes throughout; and in some roots half of the root only should have been affected. Some of the drawings shown by Brumfield (Fig. 2 and 3, and possibly 6 and 9) may be interpreted on the basis just indicated.

There are many indications that the shoot apex of the angiosperms is more complex than that of the gymnosperms. The complexity in this group appears to have been first indicated by the development of graft chimeras in solanaceous plants by Winkler (12, 13), Jorgenson and Crane (7), and possibly many others since. Graft chimeras must appear through adventitious buds formed on the very border line of union between the two grafted plants. It is most probable that in such a bud development, where an epidermal tissue alone is from one plant and the inner tissues are from the other, only a single layer of cells would have come from one of the plants. In some graft-chimeral forms where more than the epidermal tissue is from one plant and the remaining tissues are from the other, only two adjacent layers of cells would have come from one of the plants, for it would be most improbable to find a graft chimera where a tissue derived from one of the plants would be located between two tissues from a second plant. Parenthetically, it may be suggested that the occurrence of graft chimeras would be limited to plants in which adventitious buds may readily form at the union of the two grafted plants. In plants, especially those of woody structure, where adventitious buds do not readily, or never, form, the occurrence of graft chimeras would be unlikely or impossible. Reported graft chimeras in some woody plants (11) were perhaps periclinal forms of chimeras occurring naturally by some somatic mutation.

There are innumerable so-called bud sports, many of which are undoubtedly of chimera nature. If the chimera condition exists in the shoot apex these forms are in general self-perpetuating. Furthermore, the condition responsible for such a sport is most probably confined to a single layer in the apical meristem. This supposition is based on the high probability that a mutation may occur in only one layer at a time in a given region, as it is most improbable that a certain mutation should occur simultaneously in more than one of a homologous pair of chromosomes, or in two adjacent cells in either a horizontal or a vertical plane in the apical meristem.

On the basis of these presumptions and of observations on colchicine-treated plants, the following conclusions can be safely drawn: (a) If a mutation occurred in L-I<sup>1</sup> in the apical meristem of a given

<sup>1</sup>L-I, L-II and L-III refer to apical layers in the shoot apex (5).

plant, the effect of such a mutation would be expressed through the tissue that is derived from L-I, hence it would be primarily of epidermal nature. Such a mutation may also be expressed in the internal tissues when occasionally a part of the internal tissue, or in very rare instances the whole of the internal tissue, of any particular organ is derived from L-I.

(b) If a mutation occurred in L-II, the stem tissue most likely to be affected would be either the hypodermis, as in cranberry, or the external portion of the cortex, as in peach; or it may even in certain instances extend farther into the cortex and into the stele and pith, as in both cranberry and peach. In the leaves the effect of a mutation originating in L-II may be expressed mostly marginally, extending inwardly in various depths, depending upon what proportion of and to what extent the inner tissue in different areas in the leaf is derived from L-II. When the entire internal tissue is derived from L-II, then a mutation in L-II will involve that whole tissue. The above situations very probably prevail in the fruits and other organs of the flower just as in the leaves. Sporogenous tissue of the anthers is usually derived from L-II. However, if we consider histogenesis in the anthers to be similar to that of the stem or the leaf, then at times some parts of the sporogenous tissue in the anthers of a chimeral plant may be derived from L-II and some parts from L-III, resulting in an unexpected mixture of pollen grains.

(c) In the stem, L-III may give rise to part or all of the cortex (except the hypodermis, as in cranberry, and except the outer cortex, as in peach) and to the stele and pith. In the fruit, the central portion of the fleshy wall may be derived from L-III, or the whole fleshy part of the fruit may be derived from L-III, except two marginal layers of cells that will be derived from L-I and L-II. In other cases the fruit development may follow the same process as in the leaves and stems, as presented above.

Taking the developmental phases above sketched as somewhat basic, it may be possible to unravel some of the complicated patterns observed in bud sports, such as color sports of apples and sports affecting size or shape of fruits, and in variegation in leaves of some plants, and explain the histogenic processes involved in such somatic expressions.

There appears to be a striking similarity between the development of the variegation patterns in the leaves of some species of plants and the developmental pattern in the leaf of cranberry, as indicated by the studies on the cytochimeral forms. Because the variegation patterns may be clearly seen and can be examined microscopically as well, some details concerning variegation will be presented first as illustrations of what histogenic processes are probably involved in other somatic mutations, such as bud sports of fruits.

Special study was made of green and colorless patterns of variegation in leaves of some dicot and monocot plants. The dicots included: *Euphorbia pulcherrima* (poinsettia), *Citrus sinensis* (orange), *Ligustrum vulgare* (privet), *Euonymus japonicus* var. *mediopictus* (spin-

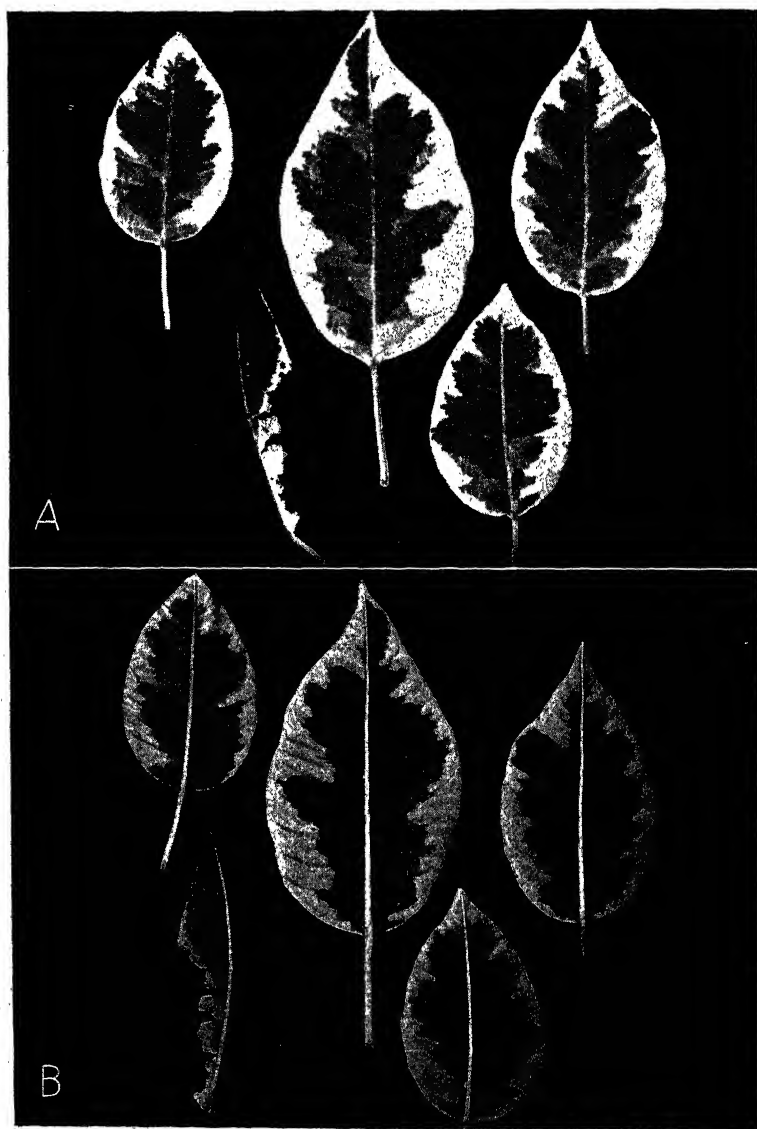


FIG. 1. Variegated leaves of *Euphorbia*. A. Upper surfaces of five leaves. Typically variegated leaves are marginally colorless and centrally green. The central area is composed of sharply defined shades of green: dark green, light green, and occasionally very light green. Very intense green colorations occasionally are found on some leaves. This appears on the upper left side of the first leaf. About three-fourths of the mutilated leaf is of the intense-green coloration.

dle tree), and *Vitis* (grape) of the *Euvitis* group. The monocots included: *Sansevieria trifasciata* var. *laurentii* (Congo Snake Sansevieria), *Pandanus veitchii* (Veitch's screwpine), and *Dracaena warneckii* (dracena).

#### VARIATIONS IN DICOTS

*Euphorbia pulcherrima* (poinsettia):—Fig. 1A shows the upper surfaces of five poinsettia leaves and Fig. 1B the lower surfaces of the same leaves arranged in the identical order of Fig. 1A. In the variegated leaves of poinsettia, viewed from the upper surface, there were found mostly two distinct green color intensities, dark green and light green, each sharply defined into various patterns. The margins of four leaves of poinsettia shown in Fig. 1A lack color completely, and in one leaf about three-fourths is colored and one-fourth is colorless (the colorless portion of this last leaf was already mutilated on the plant when discovered). In addition to such leaves as are shown in Fig. 1, occasional leaves are completely colorless. A bright dark green shade of coloring is shown in the upper left corner of the smallest leaf and on three-fourths of the mutilated leaf in Fig. 1A. Bright-green colored patches also occur, though very rarely, over the centrally colored area. The other two shades of green, those most common in poinsettia, can be seen in the marginally colorless leaves. The most dominant coloration was a dull dark green, generally located centrally, and a lighter shade of green that was mostly marginal to the dark-green coloration, but in some cases the latter extended to the midrib of the leaf. Occasionally there was also a much lighter shade of green coloration on some leaves. This can be seen in the lowermost right side of the largest leaf, near the petiole, in Fig. 1A. Usually, however, there were only two distinct shades of green on the upper surface of the leaves, dull, dark green and light green. There were also two shades on the lower surface of the leaves, shown in Fig. 1B. The lightest shade of coloration on the lower surface was found on the smallest leaf in the position of the darkest green of the upper surface shown in Fig. 1A. A similarly very light coloration was found on the left side of the lower surface of the mutilated leaf in Fig. 1B.

The portions showing the different intensities of color in the poinsettia leaves were examined microscopically by cutting freehand transsections. The aggregate result of this examination is presented diagrammatically in Fig. 2. In transection the poinsettia leaf is shown to be six to eight layers of cells in thickness, including the two epidermal layers. Of this number, one layer is the palisade and three to

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B. Lower surfaces of the same five leaves arranged in the same order. The colored areas are of the same general pattern as on the upper surfaces of the leaves, but the shades of coloration in some areas vary from the corresponding areas observed on the upper surfaces. The back of the intense-green area on the first leaf shows a very light-green coloration. On the mutilated leaf the portion on the damaged side is of light-green coloration. On the darker green half of the mutilated leaf a portion is of a lighter shade of the green. The significance of the latter shading and of others is indicated by the diagrams in Fig. 2.



five layers, most commonly three, make up the spongy tissue. In the normal leaves the guard cells in the epidermis and the cells of the palisade and spongy tissue contain chloroplasts. In the variegated leaves, ordinarily, in the green portion chloroplast development was confined to the two layers of cells of the spongy tissue beneath the palisade layer. The guard cells in all portions of the variegated leaves contained small chloroplasts. Only rarely were chloroplasts found in the cells of the palisade and in the layer of cells of the spongy tissue next to the lower epidermis. The histological significance of such a development will be discussed further on.

As was pointed out above, the green coloration in the variegated leaves was generally confined to the central portion of the leaves, and marginally the leaves were mostly colorless. In the green area there were mostly two color tones, dark green and light green. Where the intensity of color was dark green, this was found to be due to the presence of chloroplasts either in the uppermost spongy layer alone or in the two uppermost spongy layers. Where the color was a lighter shade of green, chloroplasts were present in the middle layer of the spongy tissue alone. Slight variations from the two intensities of coloration occurred when the number of spongy layers was more than three. The darkest green coloration in the smallest leaf in Fig. 1A was due to the presence of chloroplasts in only the palisade layer (left side in Fig. 2A). When in very rare cases such a brightly green coloration appeared over a centrally green coloration, chloroplasts were found in the palisade cells and in the middle layer of cells of the spongy tissue; chloroplasts were conspicuously lacking in other spongy layers of cells (right side of Fig. 2A). In the marginal area of the mutilated leaf, chloroplasts were found in all layers of cells. On the back of this leaf (lower surface view) the slightly lighter colored area on the right side of the midrib was due to the presence of chloroplasts in only one layer of the spongy tissue next to the epidermis and in the palisade layer over that portion. Where the color in the back of this particular leaf was the lightest, the spongy layer next to the epidermis was without chloroplasts, but chloroplasts were present in the upper two layers of spongy tissue and in the palisade layer. The details of the internal microscopic structure of this leaf are presented in the diagram in Fig. 2B.

*Citrus sinensis* (orange):—What has been described for the variegated poinsettia leaves was basically the same in the variegated leaves of the orange. In the orange leaves, however, there were more shades of sharply defined green coloration, viewed from both the upper and lower surfaces of the leaves (Fig. 3A and 3B, respectively) than in the leaves of poinsettia. This was found to be due to the fact that in the orange leaves (Fig. 4) there were two palisade layers of cells and from 10 to 12 layers of cells in the spongy tissue, as indicated diagrammatically in Fig. 4, whereas in the poinsettia leaves there was only one layer of palisade cells and usually three layers of cells in the spongy tissue. In the variegated orange leaves there were no areas where chloroplasts could be found in either the upper palisade cells or in the lowermost layer of cells of the spongy tissue next to the lower

epidermis. In the colorless area of the leaves no chloroplasts were found in any of the cells of the internal tissue. The difference in the shade of green coloration in the orange leaves was, as in poinsettia, mainly due to the position of the layers of cells with chloroplasts at different depths from the surface of the leaves, and only very slightly due to the number of layers of cells at a given area containing chloroplasts. Numerous variegated orange leaves were examined, but nowhere could chloroplasts be found in the first palisade layer or in the first layer of the spongy tissue next to the lower epidermis, as was occasionally the case in poinsettia (Fig. 2). So in the variegated orange leaves color was due in no case to the presence of chloroplasts in either the first palisade layer or the first layer of the spongy tissue at the lower surface of the leaf. As in poinsettia here also guard cells contained small chloroplasts.

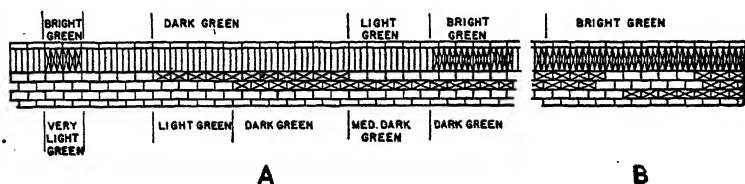


FIG. 2. Diagrammatic presentation of variegated leaves of *Euphorbia*. In cross section, leaves show upper and lower epidermis, one palisade layer of cells, and three layers of cells of spongy tissue. The cells that contain chloroplasts are shown by cross marks; those without normal chloroplasts are left blank. Epidermal cells are also shown blank.

A. Where the central color was of dark-green shade, chloroplasts were present in the upper one or two layers of cells of the spongy tissue. *Light green* is indicated by the presence of chloroplasts in the middle layer of cells of the spongy tissue. *Very light green*, in the central colored region (not shown in the diagram), was due to the presence of chloroplasts in the third layer of cells of the spongy tissue from the palisade layer, where the spongy layer was four layers thick, instead of three as shown in the diagram. *Bright green* or intense green was from the presence of chloroplasts in the palisade layer. At the bottom of the diagram are indicated the shades of coloration that appear on the lower surfaces of the leaves. This diagram shows that when the coloration is of central location in the leaves the cells of the palisade and a layer of cells next to the lower epidermis are devoid of normal chloroplasts, except where occasionally a patch of bright green coloration appears over the centrally colored area. In such cases chloroplasts were found only in the palisade cells and in the middle layer of cells of the spongy tissue. This is shown on the right side of the diagram.

B. This diagram shows the condition that was present in the mutilated leaf. In this leaf, where marginally the color was intense green, both the palisade cells and those of the spongy tissue contained chloroplasts. This is shown on the right side of the diagram. Where the color was somewhat lighter than intense green, in that portion of the leaf the cells of the palisade and a layer of cells in the spongy tissue next to the lower epidermis contained chloroplasts; the other two layers of the spongy tissue contained no chloroplasts. The left side of the diagram shows where the cells of the palisade and two layers of cells in the spongy tissue next to the palisade contain chloroplasts and a layer of cells next to the lower epidermis is devoid of chloroplasts. This illustrates the colored condition on the back of the mutilated leaf on the damaged side, where the coloring is of light shade.

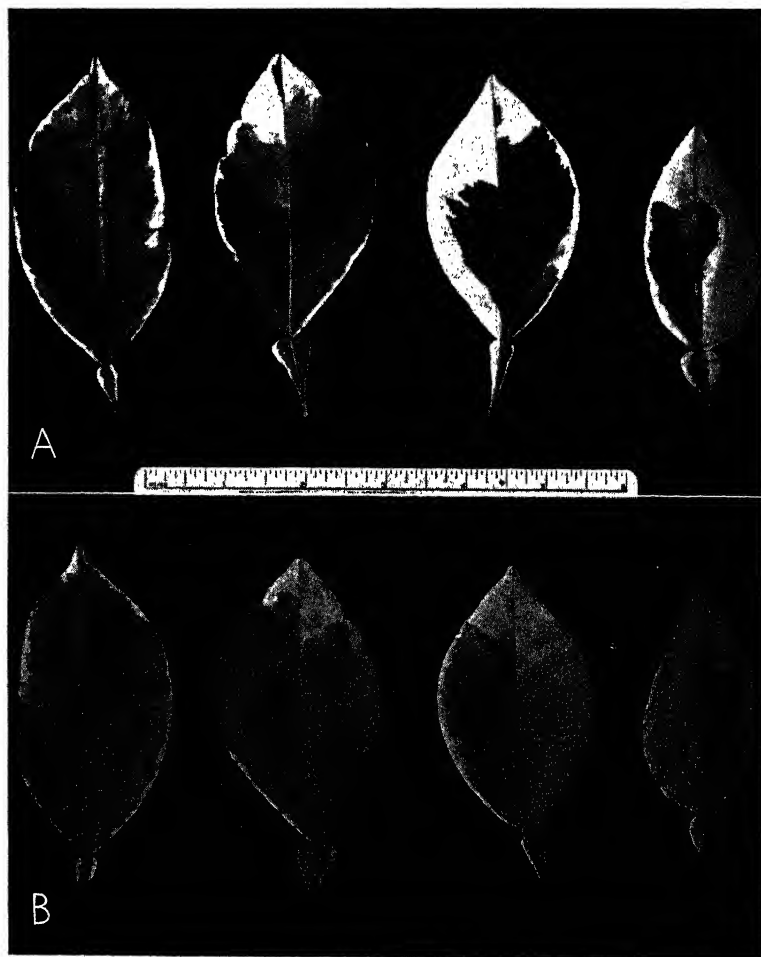


FIG. 3. Variegated leaves of citrus. A. Upper surfaces of four leaves. B. Lower surfaces of the same leaves arranged in the same order. Details in the text.

*Ligustrum vulgare* (privet):—In general, the variegation pattern in privet is like that in poinsettia and orange, except that in privet it is more variable. Privet leaves showing the range of variability in variegation pattern are shown in Fig. 5. As before, Fig. 5A illustrates the upper surfaces of the leaves and Fig. 5B the lower surfaces of the same leaves, arranged in the same order. The patterns in the second, third, and fourth leaves in Fig. 5 are comparable to those of poinsettia and orange where green coloration is central and the margin is colorless. The third leaf of privet is closely comparable to the first leaf of poinsettia, both having a small, dense green patch separated from the central green area; while the sixth, seventh, and eighth leaves of privet are comparable to the fourth leaf of poinsettia.

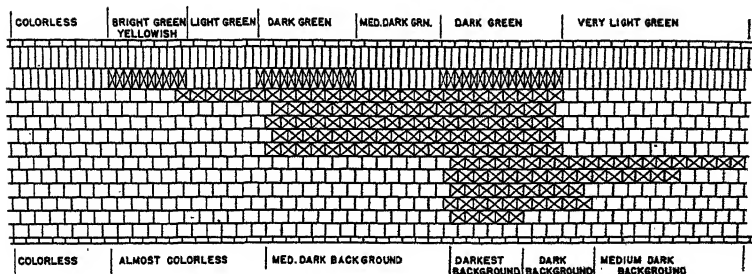


FIG. 4. Diagrammatic presentation of the variegated condition in the orange leaves, similar to Fig. 2. In orange no coloration was due to the presence of chloroplasts in cells next to either epidermis. Details in the text.

In looking over the variegated privet plants, three types of branches were found, generally speaking, as to types of leaves; each bore (a) branches on which leaves were of the typical variegated type with a central green coloration and a yellow margin (second, third, and fourth leaves in Fig. 5); (b) branches with leaves yellow without a central green coloration (fifth leaf of Fig. 5); and (c) branches with entirely bright and dense green leaves (first leaf in Fig. 5). Yellow coloration in the leaves was subject to change from almost colorless to almost green with a change in nutritional level and light conditions of the plants; but such changes did not alter either the pattern of variegation or differences in the shades of the green coloration patterns in the leaves.

Internally the privet leaf is composed of two or three (presumably two predominating) palisade layers and of a spongy tissue six or seven cells deep. Shades of coloration in the central green area in privet leaves were associated with the presence of normal chloroplasts in the layers of cells of the spongy tissue at varying distances from the upper and lower epidermis. Since the privet leaf was intermediate between poinsettia and orange leaves as to the number of cell layers in the spongy tissue, the variation in the shades of coloring in privet was also intermediate between that of poinsettia and of orange. In leaves in which the central color is dark green, normal chloroplasts were absent from all palisade layers and from the three layers of cells of the spongy tissue next to the lower epidermis; normal chloroplasts were present only in the upper three or four layers of cells of the spongy tissue next to the palisade layers. Lighter shades of green coloration were due to the presence of normal chloroplasts in the cells of the spongy tissue not immediately next to the palisade cells, as shown diagrammatically in Figs. 2 and 4 for poinsettia and orange. The small, dark-colored spot on the upper right side of the third leaf, the dark-colored area of the sixth leaf, and the irregularly shaped dark patch on the upper portion of the seventh leaf in Fig. 5 were due to the presence of normal chloroplasts in only the palisade layers in these similarly colored areas. On the back of these leaves (Fig. 5B) each corresponding green-colored area showed a very light green coloration.

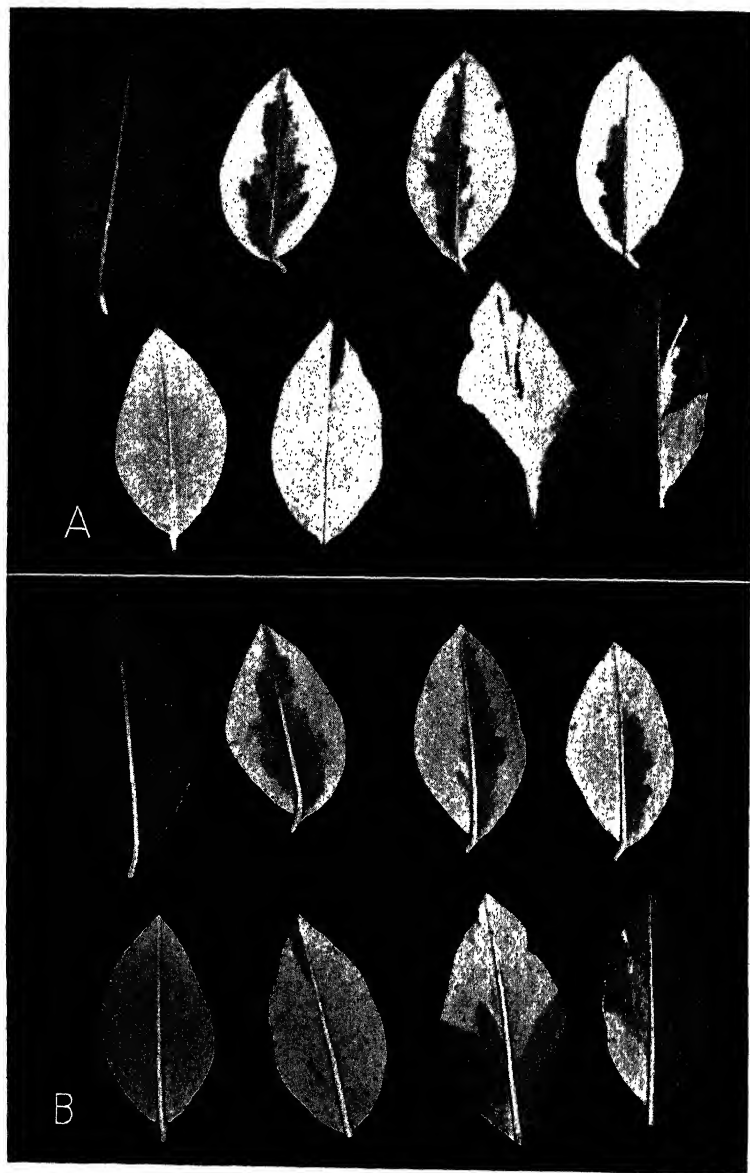


FIG. 5. Variegated leaves of *Ligustrum*. A. Upper surfaces of eight leaves. The first leaf is normal green; the second, third, and fourth leaves are typical variegated leaves with marginal yellow or colorless area and central green-colored area, dark green, medium dark green, and light green; fifth leaf is yellow or colorless. A small area of intense-green coloration is shown in the upper-right portion of the third leaf, and wider areas in the sixth, seventh, and eighth leaves.

B. Lower surfaces of the same leaves arranged in the same order. Details in the text.

tion. On the other hand, a very light green coloration at the lower portion of the sixth leaf in Fig. 5B was due to the presence of normal chloroplasts in only the first layer of cells of the spongy tissue next to the lower epidermis. The larger intense green areas of the seventh and eighth leaves were mainly due to the presence in the limits of these areas of normal chloroplasts in the cells of the palisade layers. Marginally in these green portions all the cells of the spongy tissue also contained normal chloroplasts; in some parts coloration was due to the presence of normal chloroplasts in only a few layers of cells of the spongy tissue next to the lower epidermis. In no case were intense-green areas in direct contact with green areas which formed a variegation pattern of the centrally located type, similar to that in the second, third, and fourth leaves. These two diverse types of colored areas were always internally separated by cells or layers of cells that contained no normal chloroplasts. The condition in the guard cells was the same as in poinsettia and orange.

As mentioned above, three types of branches grew, practically at random, on the variegated privet. However, often leaves were found on the typically variegated branches that were in part intense green or symmetrically half intense green and half typically variegated or totally green. Similarly the same variable degrees of intense green coloration were found on branches with yellow leaves; whereas no variation from the intense-green leaves to variegated or yellow-colored leaves was observed on green leafy branches. Furthermore, when branches that otherwise bore typically variegated leaves or yellow leaves were cut off above entirely or mostly green leaves as just described, buds at the axils of such leaves developed into branches bearing only green leaves, as in a nonvariegated normal plant.

When examined carefully, occasionally some leaves that appeared to be homogeneously green, or half green and half yellow, or half centrally green with yellow margin and the other half green, showed a faint central coloration through the green coloration of the leaves which was lighter than the green at the marginal areas of the leaves, similar to the condition described previously for the mutilated poinsettia leaf. This somewhat lighter green region showed outlines similar to colored areas shown in the second, third, and fourth leaves in Fig. 5. In free-hand sections from such a lighter green area normal chloroplasts were found to be present in the cells of the palisade layers and in one or two layers of cells of the spongy tissue next to the lower epidermis; the more internal layers of cells contained yellowish-green to almost colorless plastids in comparison to the chloroplasts in the cells at the marginal denser green areas. Plastid color difference between the two was definitely distinct.

Since microscopically the details of the internal structure of the variegated leaves of the privet were basically like those in the leaves of poinsettia and orange, no diagram is presented for the details in privet.

*Vitis* Sp. of *Euvitis* group (bunch grape):—Whereas the forms of variegation described above have long been known, the variegated form of the grape was discovered among several hundred seedlings

growing in the greenhouse in the spring of 1947 by the author on a young seedling shoot when only 15 centimeters high. The variegation on this seedling was localized along three nodes near the base. Below and above the variegated portion the leaves were entirely green. The lowermost and uppermost of the three leaves were only sectorially green and colorless. The middle leaf was fully variegated: it was centrally green and white or very faintly yellowish green over the whole margin. At first the plant was cut back just above the uppermost variegated leaf; from its axillary bud only a green shoot grew out. Later the plant was cut off just above the middle variegated leaf; from the bud at the axil of this leaf a fully variegated shoot developed. Besides this variegated shoot, other shoots grew at the lower levels of the main plant, which bore only green leaves. The latter shoots were cut off to encourage better growth in the variegated shoot.

Samples of the variegated grape leaves are shown in Fig. 6. Basically the pattern was similar to that of poinsettia. As in poinsettia, in some leaves there were as many as four shades of green coloration, in others only one. Some representative leaf samples were examined microscopically. Internally there were one palisade layer and a spongy tissue three or four (three predominating) layers of cells deep. Chloroplasts were present in the guard cells as in other variegations above. Usually the darkest shade of green was due to the presence of normal chloroplasts in all internal cells. Lighter shades were due to either lack of normal chloroplasts in the palisade cells and their presence in other cells, or to lack of such plastids in both palisade cells and cells of the spongy tissue next to the lower epidermis and their presence in only the upper layers of the spongy tissue. The first leaf in Fig. 6 appeared to be normal, but a closer examination revealed that there was an area of faintly lighter color toward the petiole. Microscopic freehand sections throughout the light-colored portion of this leaf showed that the palisade cells and one layer of cells of the spongy tissue next to the lower epidermis contained normal chloroplasts, whereas the other cells of the spongy tissue contained yellowish-green to almost colorless plastids. In the darkest green area of the first leaf all internal cells contained normal green plastids. It should be mentioned also that with a change in nutritional condition even the most colorless areas change toward green, as was the case in privet. No study was made of the second leaf in Fig. 6, but studies of the others were sufficient to learn about the internal composition of variegated grape leaves in general. In the third leaf, in the darkest green area all internal cells contained normal chloroplasts; in the medium-dark area normal chloroplasts were absent from the palisade cells, but were present in the cells of the spongy tissue next to the lower epidermis. Three shades of coloring normal chloroplasts were present in only one layer of cells of the spongy tissue next to the lower epidermis. Three shades of coloring due to the presence or absence of normal plastids at the different depths of cell layers in the leaf appear on the lower surface of the third leaf (Fig. 6B). In the lower-surface view the two extremes of color shade are more apparent than the medium coloration. In the fourth leaf, the entire margin of the leaf is colorless; the colored area is inter-

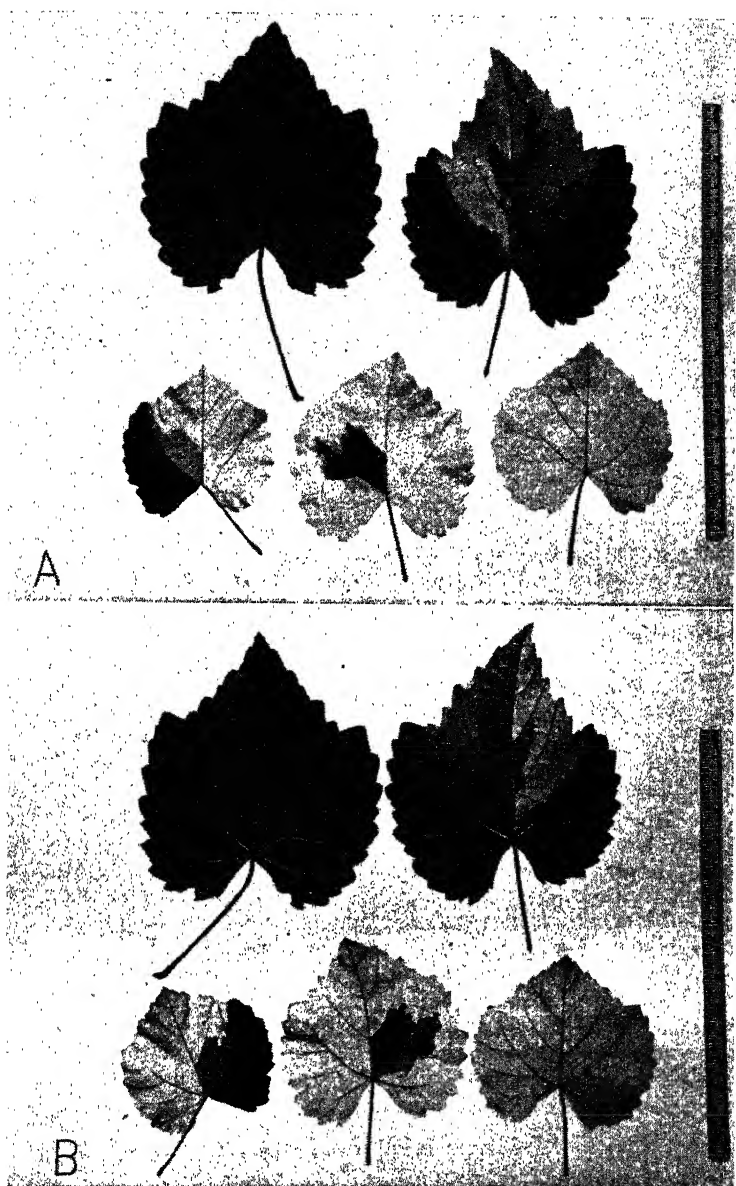


FIG. 6. Variegated leaves of *Vitis*. A. Upper surfaces of five leaves from a variegated branch. The first leaf appears to be normal green, but closer examination showed toward the base of the leaf the presence of a faintly lighter-colored area. For details of this and other leaves see the text.

B. Lower surfaces of the same leaves arranged in the same order.



nal and extends to the petiole. There are only two shades of coloration here: one medium-dark green (not intense green) and the other light green. In the dark-colored area normal chloroplasts were lacking in the palisade and in one layer of cells of the spongy tissue next to the epidermis, normal chloroplasts being present in only the upper two layers of cells of the spongy tissue. The light-green coloration was due to the presence of normal chloroplasts in only the middle layer of cells of the three-layered spongy tissue. An extremely small area of coloration is shown in the fifth leaf, close to a large vein. The minute coloration in this leaf was due to the presence of normal chloroplasts in only one layer of cells of the spongy tissue just below the palisade layer which lacked chloroplasts. A streak of coloration extended from this colored spot toward the petiole. Often in other leaves a narrow stretch of coloration would extend from the petiole close to the tip of the leaf or along the major lateral veins, or both. Such colored patches were never dissociated from the veins and were always of internal origin, as described for the coloration in the fourth and fifth leaves in Fig. 6.

*Euonymus japonicus* var. *mediopictus* (spindle tree):—In the variegated form of *Euonymus* the coloration in the variegated leaves has a reverse appearance to those described above. Marginally the leaves are green and centrally colorless (Fig. 7). There were found two types of branches growing on the same plant: (a) branches with variously patterned centrally colorless leaves, and (b) branches with only totally green leaves. On a type branches one might find leaves that are totally green. When buds at the axils of such green leaves are forced to grow, by cutting branches above them, only branches with totally green leaves are obtained. No variegated leaves are found on branches that bear totally green leaves, nor are completely colorless leaves found on any kind of branches.

In this variegated form of *Euonymus* the variegation patterns appear identical at both sides of the leaf, as in mirror images. However, when the line of demarcation between colored and colorless areas is observed closely, it will be seen that there is some overlapping at some places between the two areas. Microscopically in green areas there are fully developed green plastids. Where the green area is in contact with the colorless area there is a gradual diminution of green pigment toward yellow and complete disappearance of both pigment and plastids. This is in sharp contrast with what has been observed in other variegated plants described above. The possible significance of this will be considered further on. The guard cells at both colored and colorless areas contained chloroplasts.

#### VARIATIONS IN MONOCOTS

The variegated condition in the blades of the monocots *Sansevieria* (Fig. 8) and *Pandanus* (Fig. 9) was basically of the same nature as in the leaves of the dicotyledonous plants described above. The margin of the blades of the two monocots was colorless or showed a yellowish color. Green coloration was central, except that often more or less colorless streaks extended from the tip of the blades toward the base



FIG. 7. Variegated leaves of *Euonymus*. A. Upper surfaces of three leaves. The first leaf is normally green colored. The second and third leaves show extremes of variegation patterns in this plant. The variegation here appears as reverse of that in other plants: marginally the leaves are green and centrally colorless.

B. Lower surfaces of the same leaves arranged in the same order.

of the blades. The pattern of variegation in *Dracaena* blades (Fig. 10) was distinct from that of the other two monocot plants. In *Dracaena* there is a darker green strip at the very edge of the blade. Next, toward the center of the blade, there is a colorless strip; and the rest of the central portion of the blade is green with a dull tone.

Microscopic observations were made of freehand transections of the blades of the three monocots. The following conditions were observed:



FIG. 8. Variegated leaves of *Sansevieria*. Left blade is normal; right blade is variegated. On the left side of the latter blade, a little way from the colorless portion, a fine streak of colorless area appears with a colored background.

*Sansevieria*.—In the marginal light-yellow area the cells contained mostly degenerated or partly developed small plastids, yellowish in color. In the green area fully developed, large-sized chloroplasts were present in cells immediately next to the epidermis and farther in. Chloroplasts were lacking in the guard cells of the epidermis of the variegated blade. Incidentally, the horizontal striping in *Sansevieria* is due to large and intense-green chloroplasts in the cells in the very green stripes and to lighter-green and smaller-sized chloroplasts in the lighter stripes.

*Pandanus*.—The cells in the marginal colorless area were either devoid of chloroplasts or contained poorly developed plastids. This was also true in the guard cells. In the green portion of the leaf, chloroplasts were present in cells two or more layers of cells deep at both surfaces of the leaf. In some parts of the internal green portion where cells contained fully developed chloroplasts there

were some islands of cells that were devoid of chloroplasts. Whether this is a normal condition for the normal species of the variegated form here reported could not be verified for lack of nonvariegated specimens.

*Dracaena*.—In the marginal green portion of *Dracaena* leaf blades the cells contained chloroplasts. The guard cells in all regions contained chloroplasts also. Cells in the colorless region and one or more layers of cells next to both upper and lower epidermis in the centrally green region were devoid of chloroplasts. In the centrally green region

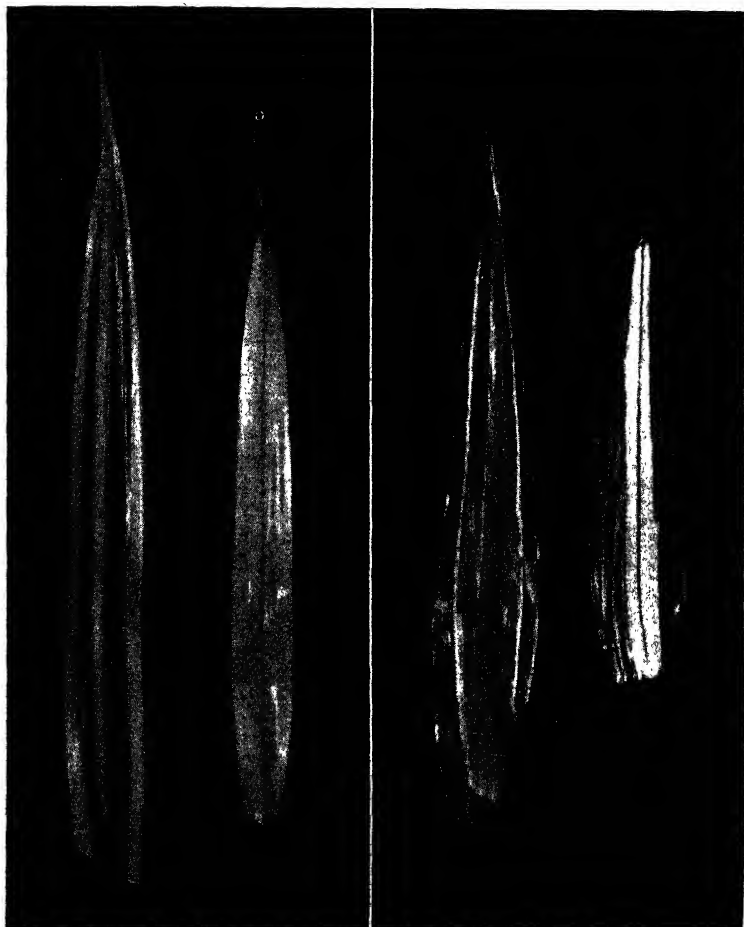


FIG. 9. (Left) Variegated leaves of *Pandanus*. Left leaf is variegated; right leaf is without normal green color.

FIG. 10. (Right) Variegated leaves of *Dracaena*. The left blade shows intense green on the very margin, and a colorless strip between the marginal intense green and a central dull green. The right blade has intense green marginally and is colorless centrally.

the other cells contained chloroplasts. As indicated above, the central green portion was separated from the epidermis by one or more layers of cells containing no chloroplasts. In *Dracaena* blades it was observed that elongated sheath parenchyma cells around the veins contained chloroplasts, but those around the veins throughout the marginal colorless area were devoid of chloroplasts.

#### DISCUSSION

The study of cytochimera forms of cranberry induced by colchicine has shown that the shoot apex has primarily three layers of cells which

more or less remain distinct from each other. These layers have been designated as primary histogenic layers. When colchicine was applied to a bud growing into a shoot or to the tip of a growing shoot, polyploidy was induced in the individual layers independently of the others, so that the various combinations of polyploid and normal layers at the shoot apex were found. By using normal and polyploid layers as markers, the origin of each tissue or region in developing stems, leaves, fruits, and so on was traced to a particular layer of the shoot apex.

In the cranberry leaf the development of the epidermis was traced to L-I, a considerable portion of the marginal area to L-II, and the central part of the leaf blade to L-III (5). The similarity of patterns of variegation in the leaves of plants described herein to the pattern of development in the cranberry leaf has strongly suggested that in the fundamentals they are alike. It is here suggested that whereas the chimera condition in the cranberry was due to the differential polyploidy in a given histogenic layer, the variegations in the plants described here are caused by a somatic mutation, whether genic, cytoplasmic, or plastidic, in only one histogenic layer in the shoot apex of the variegated plants. Thus, in the part of the leaf that is derived from the affected layer normal chlorophyll development becomes suppressed.

It appears that in poinsettia, orange, privet, and grape the affected layer is L-II. Accordingly the marginal colorless areas in these leaves are derived from L-II and the central green area from L-III. Normally epidermal cells, except the guard cells of the stomates, are devoid of chloroplasts. In the guard cells there are small chloroplasts. Therefore the epidermis is practically colorless, but nevertheless, in a genetic sense it is potentially a green tissue and is independent of other tissues of the leaves. This becomes evident from the presence of intense-green patches marginal to otherwise marginally colorless leaves of all the above plants except the orange. Significantly enough small chloroplasts were present in the guard cells, on the green as well as colorless portion of the leaves, of all the plants studied here, except in variegated *Sansevieria* and *Pandanus* alone. In cranberry there was no indication of L-I giving rise to inner tissue in the leaves. It appears that internal tissue development and the extent of such growth from L-I is variable between species. Internal tissue formation from L-I was quite-extensive in privet and grape; consequently branches bearing entirely green leaves were found along with branches bearing variegated leaves on the same plant.

The extent of tissue development from L-II and L-III was very variable and interdependent. This was evident from the amount of yellow or colorless areas and of the central green areas in the leaves. The evidence of the marginal area being derived from L-II was found from the study of freehand sections of the leaves. In the central region of leaves where the color was dark green, that area was always separated from the epidermis by a layer or layers of cells which either lacked chloroplasts or contained plastids of much lighter shade, in contrast to the chloroplasts in the layers of cells that were in the

colored portion of the internal tissue. That was further indicated when sections of intense-green areas were examined. Where the palisade cells or a layer of cells of the spongy tissue next to the lower epidermis contained intense-green chloroplasts, one or more layers next to these were always devoid of chloroplasts, or their chloroplasts never looked normal. No case was found in any variegated leaf of the plants studied in which an intense green of the nature here described merged in a histological sense with the green color of a central region (right side of Fig. 2 A). The intensity of color was determined by the depth at which the layers of cells with normal chloroplasts were from the surfaces of the leaves. The appearance of completely colorless or yellow leaves indicates replacement of L-III by L-II; and the appearance of completely green leaves indicates that L-I has replaced L-II, L-II consequently replacing L-III. Therefore, in those leaves where the mutation occurred in L-II, the green coloration in most cases should be marginal, whereas the central portion which was colored should be replaced by a tissue containing no chloroplasts or else the plastids in the cells should be yellowish. This was exactly what was found in the case of the first leaf of the grape shown in Fig. 6. This was also true in poinsettia and privet.

In all the above plants, except in *Euonymus*, there was no gradual blending of color from intense to colorless. In *Euonymus* the mutation appears to have occurred in L-III, thus showing a reverse pattern in contrast to the others. On this basis there should be at least two layers of cells over the colorless area that are potentially alike, one being the epidermis, which would be naturally practically devoid of chloroplasts and the other the palisade tissue under the epidermis, which would contain fully developed chloroplasts. If these cells contained chloroplasts, then no area in the *Euonymus* leaves should have appeared colorless. As in privet and grape, entirely green leafy shoots appear on the variegated *Euonymus* plant and they are not known ever to show variegated leaves. Therefore the variegation in this plant belongs definitely in the category of somatic mutations where the mutation is in L-III instead of in L-I or L-II. Since the colorless area shows through, it would appear that with mutation affecting chloroplast development in the central area the physiology of cells has also been affected in such a way that probably a chemical from these cells diffuses into the neighboring cells. The plastids in the adjacent cells derived from L-II are more affected and show practically no green color, but color intensity increases very rapidly in other cells at a very short distance from the true colorless area.

The fact that variegation occurs in monocots as well as in dicots indicates that this group of plants also must have distinct histogenic layers at the central growing point. Variegation in *Sansevieria* and *Pandanus* indicated that these plants have at least two histogenic layers and that the mutation responsible for the variegation involved the L-I. *Dracaena*, on the other hand, shows evidence of three layers. The mutation in this plant appears to be in the L-II. This is evident from the fact that the *Dracaena* blade at the left in Fig. 10 showed a bright-green margin, next was a colorless area, and then a central

region that was dull dark green. The blade at the right in Fig. 10 shows a variegation pattern in which it appears that growth from L-I has replaced the region that normally is derived from L-II, and that L-III is left out of it, being replaced in turn by L-II. It seems, therefore, that perhaps the other two monocots may also have three histogenic layers, but that in these plants mutation occurred in L-I instead of L-II. If the mutation had occurred in L-II instead of in L-I, the variegation patterns in these two plants would have resembled those of *Dracaena*.

In the cranberry, tissue development in leaves was traced by means of the identification of polyploidy in certain areas; it would seem that variegational patterns in leaves of such plants as are described here would serve this same purpose. By the variegation method one can simply determine the origin of the patterns and thus learn at what approximate stage of leaf development internal tissues are derived from various histogenic layers. Changes in variegation patterns and intense-green color development at the margins of leaves have indicated that in privet and grape the L-I layer may often replace L-II. In others, especially in orange, L-I may pretty well be confined to epidermal tissue development.

In fruit plants there are a number of bud sports that appear to be in the nature of periclinal chimeras. These are interpreted with the same premise as the leaf variegations and cytochimeral cranberry forms.

An example of chimeral mutation is that of thornless forms of otherwise naturally thorny blackberries (2,3). Most blackberry species are thorny. There are, however, some species that lack the thorny characteristic and breed true as thornless; also a number of cases have been found where thornless branches have appeared on normally thorny plants. In propagation of these latter thornless forms, if root pieces are used the resulting plants are thorny; hence they are always propagated by layering the tips. Occasionally on otherwise smooth canes some lateral branches have been found with as many thorns as the original plant (2). Anatomically thorns of blackberry appear to originate in the outer cortex. It appears, therefore, that a mutation suppressing or eliminating thorns has occurred in L-II of the blackberry and that L-I and L-III carry the unaffected thorny factors. On this assumption, the occurrence of lateral thorny branches on otherwise thorny canes may be due to occasional and limited cortical tissue growth from L-I. Since roots usually develop from the stele region in the stem, and that tissue in turn originates from L-III, then growth from root cuttings would have thorns. Hence, in the case of thorny branches on smooth canes, where there appears to be a process of replacement among histogenic layers, L-I gives rise to L-II, and the original L-II — the layer carrying the thornless factor — replaces L-III; root propagation from such thorny branches should result in homogeneously thornless plants.

There are at least two obvious types of sporting in pomaceous fruits that have been easily recognized and propagated; one affects fruit color and one affects fruit size. Both types are known among bud

sports of established varieties. There are two types of buds, one the naturally developing axillary buds on the growing twigs, and the other, probably exceedingly rare, the adventitious buds which, like roots, originate in the stele region and push through the bark of the stems. Since the sporting nature of the fruit plants is noticed chiefly in the fruits, the source of mutation is either in the true buds or in the adventitious buds. A normal bud would ordinarily have the histogenic layers that the plant originally had; whereas an adventitious bud, originating most likely in the stele region of the plant, would normally be histogenetically of L-III origin. Therefore, if a mutation occurred in a normal bud, then that mutation would be carried in only a single histogenic layer and hence would be periclinally chimeral. If, on the other hand, a mutation had occurred previous to the development of an adventitious bud or during its initiation, then the factor for such a mutation would either be throughout all the tissues or in a true sector extending from the epidermis into the pith.

It may be assumed that most of the color sports and perhaps the great majority of other types of sports have occurred in true buds; therefore, at least in their inception, they would be periclinally chimeral, and the factor for the sporting would be in only one of the histogenic layers. This assumption, however, could possibly be proved either by breeding methods, which would concern L-II, or by developing shoots through adventitious buds or by propagation from the roots, which would concern L-III. Whether or not a mutation factor is in L-I would be indicated by the results obtained from the breeding and root propagation methods, or possibly sectorial development from L-I. This latter may be seen on some fruits that show clearly defined color variation in sectors.

A mutation affecting size of plant organs such as fruit may result either from a genic or other somatic changes or from polyploidy. The determination of genic mutation may have to be made as suggested for color sports, whereas determination of polyploidy is rather simple. This method would require sectioning of a shoot tip to determine cytohistologically the make-up of the shoot apex. Stomate size determination with a hand lens, and pollen grain determination by measurement with a microscope would show whether the polyploidy was epidermal or subepidermal. But for the determination of innermost tissues the cytohistological method would be the most positive way.

The polyploid nature of two large-fruited forms of pear varieties has been confirmed, either by pollen grain size or by study of pollen mother cells. One large-fruited Bartlett occurred in Washington State and another in Oregon; both had large pollen grains. In England the meiosis of a large-fruited form of the variety Fertility has shown it to be a tetraploid. These determinations would indicate tetraploidy in only the sporogenous tissue. A cytohistological study of these large-fruited forms is required to determine the ploidy of the other primary tissue systems that are derived independently from the histogenic layers in the shoot apical meristem. Einset *et al.* (14) have reported the chromosome number of large-fruited forms of the McIntosh, Rome, Jonathan, and Northern Spy apple varieties. They



state: "Determinations of chromosome number were made in somatic cells in leaf and flower buds collected from branches brought into the greenhouse in late winter and kept there several days before the fixations were made. These sports were all found to be diploid, with the exception of a large-fruited Northern Spy that had a diploid layer of cells covering the inner, tetraploid tissue". The following description concerning the tree, especially of the fruit of this sport of Northern Spy, is most interesting: "The tree differed from the other trees in the orchard in that the top was flatter and the angles of the branches were wider than on typical Spy. The fruit, which first drew attention, was unusually large. A few apples were symmetrical, while others had large and small segments". This evidence of a polyploid chimeral condition in a large-fruited apple and its effect on size of the fruits and particularly "large and small segments" of this large-fruited bud sport of apple, is in conformity with the cytohistological condition described for some chimera polyploid cranberries. Dr. E. S. Degman, in a personal communication, described a similarly irregular condition in some fruits of the large-fruited Bartlett pear originated in Oregon, thus indicating that this pear is also a periclinal chimera sport; that L-II is tetraploid; and that L-I and L-III are diploid.

#### SUMMARY

A most significant resemblance was indicated between the pattern of tissue formation in the leaves of diplo-tetraploid periclinal forms of cranberry and the chlorophyll variegation patterns in the leaves described here. In cranberry it was found that the epidermis of the leaf was derived from L-I, a considerable portion of the marginal area from L-II, and the portion central to the leaf from L-III. In the variegated plants it is assumed that a mutation, whether genic, cytoplasmic, or plastidic, is involved, which has affected chlorophyll development in plastids. The affected layer in the variegated plants is recognized from the lack of normal chlorophyll development in certain areas of the leaves. It appears that in the dicots studied, *Euphorbia*, *Citrus*, *Ligustrum*, and *Vitis*, the mutation was in L-II; and in *Euonymus*, in L-III. In the monocots the mutation was in L-I in *Sansevieria* and *Pandanus*, and in L-II in *Dracaena*.

It was pointed out that sporting in fruit plants, such as thornlessness in some blackberries and color sports and giant sports in apples and other fruits, can be interpreted on the same basis as in cranberry. Thus, after recognizing the periclinal nature of these various sports and the tissues involved, we may be able to isolate them by various means from periclinal into homogeneous forms.

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## Some Effects of Ammonium Sulphate and Wettable Sulphur on Apple Leaves<sup>1</sup>

By J. C. BATES and WM. F. PICKETT, *Kansas Agricultural  
Experiment Station, Manhattan, Kans.*

IN some unpublished research the authors attempted to measure the rate of photosynthetic activity in the apple by the increase in total dry weight per square meter ( $m^2$ ) of leaf area measured at the end of the growing season. The variation in values obtained between trees, even within a treatment group, was high and the difference in values obtained between treated and untreated trees was not statistically significant. These measurements were based on the assumption that changes in leaf area occur at the same time in all trees under investigation and that the proportionate rates of change in leaf area between different trees remain constant throughout the growing season. Since this assumption did not agree with observations of the authors, it seemed desirable to obtain the product of the square meters of leaf area and hours of exposure to daylight (square meter hours,  $m^2h$ ) and measure the rate of photosynthesis in increase in total dry weight per tree per  $m^2h$  of leaf area. It was desired to determine also the chlorophyll content of the leaves and the influence of the ratio of the internally exposed surface to the external surface (R value) of the leaf on the rate of photosynthesis. Therefore, a combination treatment of nitrogen fertilizer and wettable sulphur foliage spray, with which an increase in the R value of apple leaves had previously been obtained, was selected for this study.

### METHODS OF PROCEDURE

The dry weight of the 26 Jonathan apple trees used in the experiment was calculated at the time of planting on January 21, 1946 from the fresh weight of the trees and the percentage of moisture in four extra trees from the lot.

The trees were planted in wooden boxes measuring 12 by 12 by 15 inches and plunged into a ground bed of a greenhouse. Precautions were taken to prevent the influence of any differences in light intensity, soil composition, drip from the sprayed trees, methods of sampling, and selection of trees to be treated on the experimental results.

Thirteen trees were given the following combination treatment: 3 ounces of ammonium sulphate applied to the soil around each tree on February 18, 1946 and 12 applications of wettable sulphur foliage spray, formula of 5.4 pounds to 100 gallons of water, applied on the following dates: February 26; March 6, 11, 18, 26; April 1, 9, 16, 23; and May 1, 9, 15, 1946.

To obtain the  $m^2h$  of leaf area, the growing season was divided into 15 consecutive periods of approximately 7 days each. The leaf area of each tree was measured at the beginning and end of the growing season and between consecutive periods. The  $m^2h$  of leaf area of each

<sup>1</sup>Contribution No. 215, Department of Horticulture.

tree for each of the 15 consecutive periods was calculated from the formula:

$$m^2h = \frac{m^2 \text{ of leaf area at beginning of period} + m^2 \text{ of leaf area at end of period}}{2} \times \text{total number of day-light hours in period}$$

The sum of the  $m^2h$  of leaf area of all 15 periods gives the total  $m^2h$  of leaf area for the growing season.

The leaf area of a tree was calculated from the sum of the products of the length and width of all leaves on the tree and the ratio of the sum of the products of the length and width to a planimeter measurement of area of a random sample of leaves. The measurements of the leaves in the random sample were made from blueprints of the leaves.

On May 23, 1946 the  $R$  value ( $R$ ) of four leaves from each tree was calculated from measurements of the depth of palisade tissue in microns ( $P$ ) using the formula ( $R = 0.1122P + 1.33$ ) developed by Pickett and Birkeland (1).

The chlorophyll content of the leaves was determined for each tree using the method described by Compton and Boynton (2).

The increase in grams of tree dry weight was obtained by subtracting the calculated dry weight at planting time from the total dry weight of the tree (including leaves) at the end of the growing season.

### EXPERIMENTAL RESULTS

One of the treated trees, No. 17, died without breaking dormancy. Three of the treated trees, Nos. 3, 7, and 13, were so severely injured by the treatment that the leaves died at the tips and margins. All of the remaining trees appeared healthy. The untreated trees, however, appeared to have longer shoots with more foliage than those of the treated trees. The trees varied considerably in the time required to break dormancy.

A coefficient of correlation of +.995 was obtained between the area and the product of the length and width of the leaves.

The average gain in grams of dry weight per tree during the growing season was 47.57 and 85.70 for the treated and untreated trees respectively.

The average size of the leaves of the treated and untreated trees was 12.82 and 15.78 square centimeters respectively.

An analysis of variance showed that the differences between the average size of leaves of treated and untreated trees was significant,  $P = .02$ .

The average chlorophyll content of the leaves of the treated and untreated trees is 296 and 282 milligrams respectively per square meter of leaf area.

The average daily increase or decrease in leaf area of each tree during three of the fifteen periods of the growing season is shown in Table I.

The data in Table I show that the average daily rate of change in leaf area varies with different trees and with different periods of the growing season.

TABLE I—LEAF AREA MEASUREMENTS FOR THREE PERIODS OF THE GROWING SEASON (1946)

Tree No.	Change in Leaf Area (cm <sup>2</sup> )*			m <sup>2</sup> h : M <sup>2</sup> **		
	5th Period	10th Period	15th Period	5th Period	10th Period	15th Period
1	47	60	23	198	424	877
2	24	33	22	177	426	759
3	4	-1	2	257	707	1,295
4	30	52	37	205	392	811
5	28	16	4	211	511	1,020
6	27	37	18	216	440	901
7	20	16	1	143	484	1,170
8	35	91	26	203	400	886
9	36	25	25	137	453	848
10	25	57	55	176	389	689
11	9	52	-1	272	493	1,013
12	33	95	3	229	453	1,013
13	1	3	-2	192	598	1,852
14	33	67	22	235	474	1,004
15	8	16	19	266	614	1,026
16	23	127	27	206	359	892
18	51	38	37	77	353	701
19	19	127	58	247	391	699
20	46	44	50	77	319	618
21	18	92	18	250	459	855
22	33	82	22	175	387	737
13	20	55	37	257	501	889
24	77	42	17	107	422	817
25	27	37	11	216	472	917
26	-12	69	1	288	424	852

\*Average daily increase or decrease (minus sign) in leaf area in cm<sup>2</sup> during period.

\*\*Ratio of square meter hours to square meters of leaf area at end of period.

The data show also that the leaf area of four trees decreased during one of the three periods shown in the table. Decrease in leaf area of eight of the thirteen untreated and ten of the twelve treated trees was obtained during one or more of the fifteen periods. The decrease in leaf area may be accounted for by a retarding or cessation in the production and expansion of leaves and shrinking of leaves with aging.

The data in Table I show, moreover, that the proportionate rates of change in leaf area between different trees, even between different treated (odd numbered) or untreated (even numbered) trees, does not remain constant throughout the growing season.

The difference in average daily increase in cm<sup>2</sup> of leaf area between treated and untreated trees during each of the 15 periods of the growing season is shown in Fig. 1.

The graphs in Fig. 1 show that the average daily increase in leaf area of all untreated trees was greater than that of all treated trees.

The average daily increase obtained for the treated and untreated trees was analyzed by statistical analysis of variance with the result that the difference in values obtained between the treated and untreated trees is highly significant,  $P < .001$ .

If changes in leaf area occur at the same time in all trees under investigation and the proportional rates of change in leaf area between different trees remain constant throughout the growing season, it follows that there should be no variation between trees in the ratio of the product of the square meters of leaf area and hours of exposure to daylight (m<sup>2</sup>h) during a given period to the square meters (m<sup>2</sup>) of leaf area measured at the end of the period.

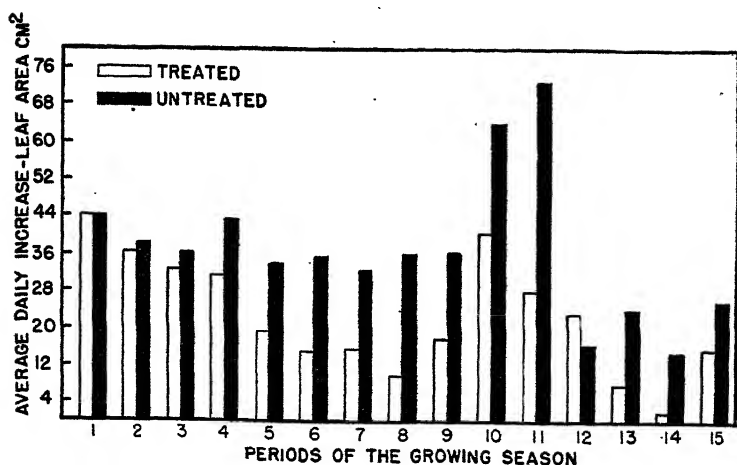


FIG. 1. Average daily increase in leaf area of all treated and all untreated trees during each of the fifteen periods of the growing season (1946).

The data in Table I show that the ratio of square meter hours to square meters of leaf area obtained at the end of the 5th, 10th and 15th periods of the growing season increases throughout the growing season for all trees and varies greatly in different trees even within a treatment group.

The graphs in Fig. 2 show that the average  $m^2h:m^2$  obtained for all treated trees was higher than that obtained for all untreated trees.

The average ratios obtained for the treated and untreated trees were analyzed by statistical analysis of variance with the result that the difference in values obtained between the treated and untreated trees is highly significant,  $P < .001$ .

Data on different leaf measurements in relation to rate of photosynthesis are shown in Table II. Due to severe injury resulting from the treatment, the data on trees Nos. 3, 7, and 13 are not included in this table.

The data in Table II were analyzed by statistical analysis of variance with the following result: although the average R value of the leaves obtained for the treated trees was higher than that of the untreated trees, the difference in average values obtained between the treated and untreated trees is not significant,  $P = .14$  and is within the bounds of reasonable sampling variation.

The average increase in tree dry weight per unit of leaf area determined at the close of the experiment for the untreated trees is slightly higher than that of the treated trees, but the difference in values obtained between the treated and untreated trees is not significant and is within the bounds of reasonable sampling variation.

The average increase in grams of tree dry weight obtained per square meter hour and per square meter hour per unit of R value was higher in the untreated than in the treated trees and the difference in

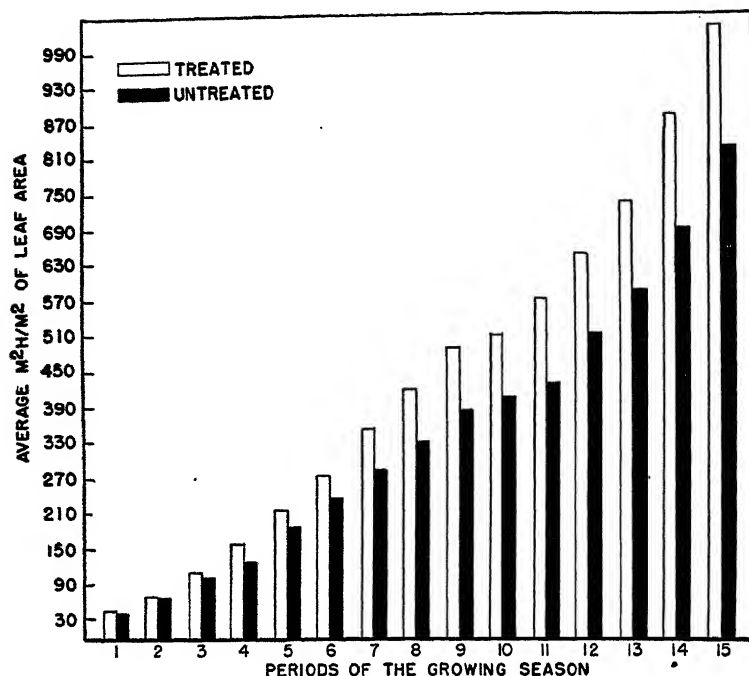


FIG. 2. Ratio of square meter hours to square meters of leaf area for all treated and all untreated trees at the end of each of the fifteen periods of the growing season (1946).

TABLE II—INFLUENCE OF TREATMENT ON R VALUE OF LEAVES AND RATE OF PHOTOSYNTHESIS IN GREENHOUSE GROWN JONATHAN APPLE TREES (1946)

Treated Leaves (R Value)	Un-treated Leaves (R Value)	Increase in Tree Dry Weight Per Unit of Leaf					
		Square Meter		Square Meter Hour		Square Meter Hour Per Unit R Value	
		Treated (Grams)	Untreated (Grams)	Treated (Grams)	Untreated (Grams)	Treated (Grams)	Untreated (Grams)
14.95	15.92	232	228	0.2645	0.3004	0.01769	0.01887
15.16	14.78	230	249	0.2257	0.3064	0.01488	0.02073
13.68	14.65	169	266	0.1998	0.2955	0.01460	0.02017
15.33	14.65	243	252	0.2400	0.2842	0.01565	0.01940
15.28	14.40	206	122	0.2004	0.1774	0.01311	0.01232
15.66	14.52	148	243	0.2122	0.2399	0.01355	0.01652
15.71	15.37	198	248	0.2316	0.2471	0.01474	0.01607
15.33	15.16	205	234	0.2302	0.2624	0.01501	0.01731
15.33	14.18	202	185	0.2199	0.2646	0.01434	0.01865
	12.66	—	143	—	0.2309	—	0.01824
	14.44	—	185	—	0.2503	—	0.01733
	13.38	—	217	—	0.2656	—	0.01985
	15.71	—	192	—	0.2258	—	0.01437
15.16*	14.60	204	213	0.2249	0.2577	0.01484	0.01768

\*Averages.

values obtained between treated and untreated trees was significant in the former,  $P < .05$  and highly significant in the latter,  $P = .007$ .

When the increase in grams of total dry weight per square meter of leaf area measured at the end of the growing season is used to compare photosynthetic rates in different trees, the time unit or length of exposure of leaf area to light varies with different trees to such an extent that the difference in photosynthetic rates obtained between treated and untreated trees is not significant. When the  $m^2h$  unit is used, the unit of time is the same for all trees and the difference in photosynthetic rates obtained between treated and untreated trees is significant. When the  $m^2h/R$  unit is used, the difference in photosynthetic rates obtained between treated and untreated trees is highly significant. Since the  $R$  value introduced is calculated from and is directly proportional to the depth of palisade tissue, the  $m^2h/R$  unit used is more nearly a measurement of leaf volume than area which makes considerable difference in the results obtained when leaves of different thickness are compared.

There was no significant correlation between  $R$  value of the leaves and increase in grams of tree dry weight per  $m^2h$  of leaf area between the treated and untreated trees.

#### DISCUSSION OF RESULTS

The leaves of treated trees Nos. 3, 7, and 13 were so severely injured by the treatments that portions of the leaves adjacent to the tips and margins died and the production of new leaves was suppressed early in the growing season. During the entire period trees Nos. 3 and 7 show an increase of only .0938 and .0818 grams respectively and tree No. 13 a decrease of .0251 grams of tree dry weight per  $m^2h$  of leaf area. The rate of photosynthesis in these trees is far below the values shown in Table II for the other treated trees. Moreover, some of the roots of tree No. 13 were killed by the treatments.

Since the production of leaf area and rate of photosynthesis were decreased in the healthy-appearing treated trees as well as in the definitely injured treated trees below that of the untreated trees, it seems highly probable that the healthy-appearing treated trees also were injured by the treatment.

Pickett and Kenworthy (3) obtained a coefficient of correlation of  $+ .70$  between increase in tree dry weight per  $m^2$  of leaf area and the  $R$  value of the leaves of young York, Jonathan, and Wealthy apple trees and suggested using  $R$  value of the leaves as an index of photosynthetic activity.

The results obtained in this experiment suggest the possibility that a given treatment may increase the  $R$  value of the leaves and at the same time decrease photosynthetic activity by its injurious action on the leaves without greatly affecting the healthy appearance of the trees. In such instances, the  $R$  value of the leaf is an unreliable index to photosynthetic activity.



## SUMMARY

1. A 3-ounce application of ammonium sulphate fertilizer applied early in the growing season and twelve applications of wettable sulphur foliage spray, formula of 5.4 pounds to 100 gallons of water, injured the leaves of Jonathan apple trees growing in the greenhouse. Three trees were so severely injured that portions of the leaves died, while the other treated trees, although injured, were able to retain a healthy appearance.

2. The leaf area of a tree can be satisfactorily determined from measurements of the length and width of all leaves on the tree.

3. The average size of leaves and gain in tree dry weight was greater in the untreated than in the treated trees but there was no significant difference in the chlorophyll content of the leaves of the treated and untreated trees.

4. The average daily rate of change in leaf area varies with different periods of the growing season and with different trees. The leaf area of a tree may decrease instead of increase during some periods of the growing season which is attributed to a retardation or cessation in the production and expansion of leaves and a shrinking in area of leaves with aging.

5. The ratio of the product of the square meters of leaf area and hours of exposure to daylight ( $m^2h$ ) to the square meters ( $m^2$ ) of leaf area measured at the end of the growing season varies greatly with different trees and is higher for the treated than for the untreated trees.

6. No significant correlation was found between R value of the leaves and increase in tree dry weight per  $m^2h$  of leaf area.

7. There was no significant difference between treated and untreated trees in the grams of increase in total dry weight per square meter of leaf area measured at the end of the growing season.

8. The increase in grams of tree dry weight per  $m^2h$  and per  $m^2h/R$  of leaf was significantly greater in the untreated trees than in the treated trees.

9. The greater increase in tree dry weight per  $m^2h$  and per  $m^2h/R$  of leaf in the untreated than in the treated trees and the lack of a significant correlation between R value of leaves and increase in grams of tree dry weight per  $m^2h$  of leaf area between treated and untreated trees is attributed to the injurious action of the treatments on the leaves of the treated trees whereby their photosynthetic activity was reduced.

10. When the leaves of a tree are injured by treatment, the R value of the leaves may not be a reliable index to photosynthetic activity.

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## Magnitude of Residues on Apples from Orchards Sprayed With Organic Mercurials<sup>1</sup>

By FRANK L. HOWARD and FRANK S. SCHLENKER, *Rhode Island State College, Kingston, R. I.*

MERCURY compounds have been recognized as excellent fungicides, but their use in sprays and dusts for the control of foliage and fruit diseases has been avoided because of their poisonous potentialities to man and higher animals. No tolerance has been established by governmental agencies as to the amount of mercurial residue that can be present in foodstuffs for human consumption. During the past four years it has been demonstrated that certain water-miscible phenyl mercury compounds are effective both as protectant and eradicant plant disease control agents. Some have been shown to possess the ability to "burn out" pathogenic fungi that have already established a disease relationship with the host plant. Yet, at effective dosages the toxicant generally does not injure healthy tissues. Thus, the water-miscible mercurials provide the orchardist with a new agent, chiefly as a replacement for lime sulfur, to combat disease. This study contributes data on the quantity of mercury that may be found on apples from orchards sprayed under various climatic conditions.

In order to determine the exact amount of residue retained under various orchard conditions, samples of fruits were assembled at the Rhode Island Experiment Station and subjected to chemical analysis. Seven lots of fruit were collected from four states in the fall of 1944 (Table I) and 25 lots of five varieties from eight states in 1945 (Table II). All fruits were kept undisturbed in cold storage until the time of making the analysis and only sound fruits were used.

Commercial, Food and Drug Administration, and Experiment Station chemists were consulted regarding the best precision method for measuring micro amounts of mercury; that of Marin (1) using dithiazone at pH 1.0 was chosen. Quadruplicate 500-gram samples were taken of each lot of apples, wiped with filter paper, and peeled. The filter paper and peelings were digested, under reflux, in 750 milliliter wide-mouthed Erlenmeyer flasks with 100 cubic centimeter each of concentrated  $\text{HNO}_3$  and  $\text{H}_2\text{SO}_4$ . The digests from the apple peelings were filtered and made to 500 milliliter. Digestion was completed in a special apparatus, which trapped water, acids, and any volatile mercury. A standard sample of mercury, digested similarly, gave a 100 per cent recovery. The determination of mercury in the digested apple peelings was made on 10 and 20 milliliter aliquots. Transmittance of the mercury dithizonate was measured in a Coleman Universal spectrophotometer at 490 mu wavelength. Results are summarized in Table I.

The 1945 samples were similarly analyzed. Some of the mercury values were high as compared to those obtained in 1944 and most of those obtained in 1945 (Table II). Consequently for comparison,

<sup>1</sup>Contribution No. 696 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

TABLE I—MERCURY RESIDUE ON APPLE FRUITS SPRAYED WITH PURATIZED (PHENYL MERCURIC TRIETHANOL AMMONIUM LACTATE) AT VARIOUS DOSAGES, TIMES AND LOCALITIES (1944)

Fruit Sample	Fungicide	Concentration of Toxicant	Variety	Location (State)	Cooperator	No. of Sprays	Elapsed Days†	Hg/Ppm of Fruit
1	N5X*	1:7500	—	N. Y.	Palmiter	6	—	0.02
2	N5X	1:8620	McIntosh	Maine	Folsom	7	56	0.04
3	N5D	1:10,000	Baldwin	R. I.	Howard	5	72	0.05
4	N5D	1:13,000	McIntosh	R. I.	Howard	5	72	0.06
5	N5D	1:20,000	Baldwin	R. I.	Howard	5	72	0.04
6	N5D	1:15,000	Greening	N. J.	Daines	2	17	0.19
7	Fermate	1-½ lbs./100	McIntosh	R. I.	Howard	5	72	0.03

\*Puratized; N5X (4.5 per cent Hg), N5D (8.7 per cent Hg).

†Weathering; days between last application and picking.

analyses were also made by the Laug A.O.A.C. (2) method of dithiazone extraction at pH 6.0. Twelve samples were compared and the averages of the resulting values are as follows:

pH 1.0      0.001338 grains of mercury per pound of fruit or 0.193 ppm.

pH 6.0      0.001299 grains of mercury per pound of fruit or 0.187 ppm.

To check the amount of mercury normally present in apples, fruit purchased in a grocery store was rubbed and washed, and, upon analysis, was found to contain 0.000012 grains of mercury per pound (Table II, No. 25). Rhode Island Baldwin sample, (Table II, No. 16) sprayed with lead arsenate only, contained 0.000049 grains of mercury per pound. These two results are in the same range and are considerably lower in mercury content than apples from New York (Table II, Nos. 11, 12, 14) which were sprayed with flotation paste sulfur and Fermate.

## DISCUSSION

In some regions water-soluble organo-mercurials (Puratized Agricultural Spray) are replacing liquid lime sulfur as an eradicant fungicide for apple scab. In commercial practice they generally have given best control when applied through the first cover spray application and then followed by wettable sulfur or a dithiocarbamate (Fermate). There arises the question of what dose of mercury, of a given organic form is injurious to animals and human beings.

DeNavarre (3) states that "the human body stream can handle daily a few thousand gamma of mercury in the form of a soluble mercurial". "No dangerous mercury reservoirs are formed as in the case of lead". For phenyl mercury salts he indicates that an exact danger level cannot be given, but it probably lies between 1 ppm and 20 ppm based on the total body weight. Legally at present any quantity of mercury added to fruit might cause it to be declared adulterated. Burkholder and Lehker (4) report that the surface of an apple at the calyx stage is about 0.16 square inches and about 12.5 square inches at maturity. Growth would thus dilute the residue 78 times if application of the mercurial fungicide is discontinued at the calyx stage of

TABLE II—MERCURY RESIDUE ON APPLE FRUITS SPRAYED WITH FUNGICIDES AT VARIOUS DOSAGES, TIMES AND LOCALITIES (1945)

Fruit Sample	Fungicide	Concentration 100 Gal	Variety	Location (State)	Cooperator	No. (Hg) Sprays	Picking Date	Elapsed Day†	Hg/Ppm of Fruit
1	N5E*	8 oz	Stayman	Ohio	Winter	(4)	Oct 1	152	0.298
2	N5E	16 oz	Golden Delicious	Ohio	Winter	(7)	Sep 24	38	0.023
3	N5E	7 oz	McIntosh	L. I., N. Y.	Pyenson	(7)	Sep 12	34	0.330
4	N5E	6.4 oz	Golden Delicious	Illinois	Powell	(4)	Oct 12	147	0.031
5	N5E	7 oz	McIntosh	Conn	Kilbourn	(1)	Sep 18	25	0.190
6	N5E	7 oz	McIntosh	Mass	Boyd	(10)	Sep 11	48	0.036
7	N5E	7 oz	McIntosh	Mass	Boyd	(7)	Sep 11	94	0.027
8	N5E	8 oz	McIntosh	Mass	Boyd	(4)	Sep 11	125	0.029
9	N5E	9 oz	McIntosh	N. Y.	Palmiter	(4)	Sep 8	85	0.190
10	N5E	10 lbs	McIntosh	N. Y.	Palmiter	(4)	Sep 8	66	0.025
11	Sulphur paste	1.5 lbs	McIntosh	N. Y.	Palmiter	5	Aug 31	92	0.056
12	Permate	8 oz	McIntosh	N. Y.	Palmiter	6	Aug 31	99	0.091
13	N5E	8 oz	Golden Delicious	N. Y.	Palmiter	5	Oct 5	137	0.240
14	Permate	1.5 lbs	Golden Delicious	N. Y.	Palmiter	5+	Oct 5	137	0.035
15	N5E	8 oz	Baldwin	N. Y.	Palmiter	(5)	Oct 5	137	0.097
16	None	9 oz	Baldwin	R. I.	Howard	0	Oct 10	72	0.037
17	N5E	9 oz	McIntosh	R. I.	Howard	(7)	Sep 22	54	0.047
18	N5E	9 oz	Baldwin	R. I.	Howard	(7)	Oct 10	72	0.044
19	804	3 oz	Baldwin	R. I.	Howard	(7)	Oct 10	50	0.033
20	N5E	7 oz	McIntosh	R. I.	Howard	(7)	Sep 14	113	0.037
21	N5X	6.7 oz	Rome	N. J.	Daines	(3)	Sep 8-13	137	0.357
22	N5X	20 oz	Rome	N. J.	Daines	(3)	Sep 8-13	113	0.059
23	N5X	6.7 oz	Rome	N. J.	Daines	(3)	Sep 8-13	113	0.0017
24	N5X	6.7 oz	Rome	N. J.	Daines	(3)	Sep 8-13	113	0.0017
25	N5X	6.7 oz	Rome	N. J.	Schlenker	(3)	Sep 8-13	113	0.0017

\*Puritized; mercury content N5E 4.0 per cent, N5X 4.5 per cent, and 804 2.7 per cent.

†Weathering days between last application and picking.

fruit development, as is common practice. The absolute amount of residue would remain except for weathering, which accounts for a variable degree of removal. In Texas an aqueous mercurial (1:10,000) for Diplodia rot control on lemons is being used commercially. Reported analyses of treated fruits indicate a deposit of 1.3 to 4.6 ppm of mercury on the peel, but washing purportedly reduces this to zero. The residue of mercury found on apples in the Northeast sprayed with mercurials is several times less than the deposit on lemons, even though they are not usually washed before sale.

Generalizations cannot be made, apparently, with regard to the quantity of mercury residue on fruit, the interval elapsing between the last application and picking time, or the number of sprays applied during the season. This study contributes data to help answer the question of how much mercury residue may be expected on apples, which may aid toxicologists in determining the "safeness" of such fungicides.

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## Notes on the Setting of Delicious, 1946<sup>1</sup>

By R. H. ROBERTS, *University of Wisconsin, Madison, Wis.*

POOR crops of Delicious and its red sports are common in many orchards in the Eastern United States. There are several factors which are known to contribute to this situation: This variety has a blossom structure which permits honey bees to extract nectar without pollinating the blossom in as many as 80 per cent of their visits (4). It also has short pistils which are not always touched by those bees which are collecting pollen. At times, at least, during the blossoming season, bees have a preference for other varieties. Delicious has heavy second and June drops of blossoms which have been pollinated (3). This "nutritional" dropping is shown by the almost rare occurrence of two fruits on a spur. The Delicious blossom is quite subject to injury from spring frosts (5). Temperature conditions at blossom time (warm nights) also appear to play a role in the prevalence of poor yields of Delicious (6).

A survey was made this summer to record the cropping of Delicious over a wide range of geographic and cultural conditions.<sup>2</sup> Data were taken in 166 plantings from Arkansas to Nova Scotia (Fig. 1). Because of frost damage, some areas as Central Ohio and Western Pennsylvania were largely avoided. The procedure was to determine the



• FIG. 1. Map showing locations of communities where data were collected on the setting of Delicious, 1946.

<sup>1</sup>Published with the permission of the Director of the Agricultural Experiment Station.

<sup>2</sup>Supported in part by a grant from Stark Bros. Nursery, Louisiana, Mo.

setting on Delicious trees and also on trees of other varieties, as an indication of the pollination and nutritional level of the orchard. Direct comparisons between trees or orchards should not be made but the percentages set should be referred to a standard. This is because of the marked inverse relation of percentage of blossoming to percentage set (Fig. 2). That is, trees or branches with many blossoms have low

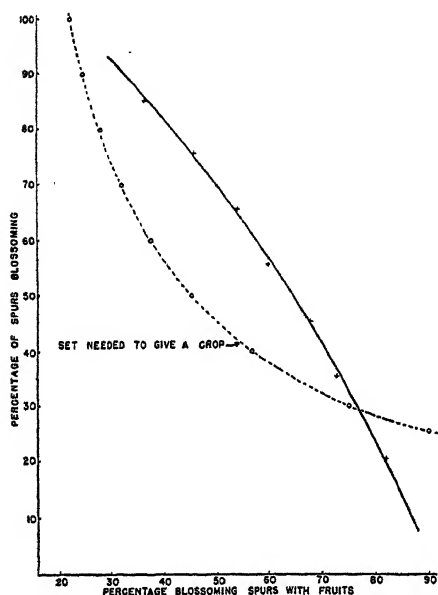


FIG. 2. Heavy line shows the relation of blossoming and setting of Delicious in 1944. Crosses indicate averages for 1946. The broken line shows the percentage set needed to give 22.5 per cent of total spurs fruiting with different amounts of blossoming.

percentages of set and those with few blossoms have high percentages of blossoming spurs with fruits on at harvest time. The comparisons of setting between orchards was made by comparing the percentage set with the average condition for trees of a like amount of blossom (Fig. 2). Likewise, the setting of other varieties was compared to the standard for Delicious (Fig. 3). Very few kinds set more poorly than Delicious under average orchard conditions. Typical cases are R. I. Greening and Twenty Ounce.

Good crops were found scattered throughout the East; the apples needed thinning or were thinned in many orchards. Many orchards had very poor crops.

Crop and set should not be confused. They are not the same thing. A crop is produced when approximately 20 to 25 per cent of the total spurs on a tree bear fruits (2). The percentage set refers to the number of spurs bearing fruits out of each hundred that produced blossoms. The percentage set needed for a crop varies with the amount of blossom. By reference to Fig. 2 it is seen that 24 per cent blossom set of a 90 per cent blossom would yield a crop, as also would a 75 per cent set of a 30 per cent blossom. These are actually below the average recorded situations. (One item is different. This is the quality of fruit. The grade of fruit is much better with the good setting of a small amount of blossom.) On branches which are sufficiently vigorous to have only 40 to 70 per cent of the spurs blossoming (Fig. 7) it is common for more than enough apples to set to give a good crop. With more blossoms, on weaker wood, the

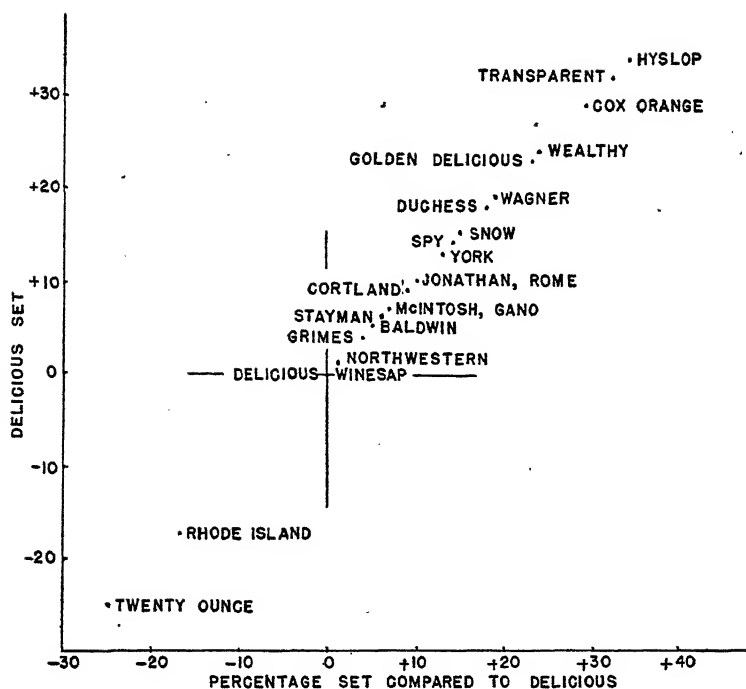


FIG. 3. Diagram of average setting of different varieties compared to Delicious. The percentages plotted are above (+) or below (—) the average shown in Fig. 2 (solid line).

size of the fruit is too small. These situations explain why the data on Delicious cropping were taken in terms of set and not yields. Crops are not comparable because like amount of apples may result from widely different amounts of blossom. Percentage sets give an apparently accurate index of the pollination (and nutritional) conditions in the orchard. Also, there is a large difference in the amount of blossom on different branches of the same tree, depending upon the vigor of the branch (Fig. 2). This fact makes a record of the percentages set important when trying to judge pollination conditions.

The setting of Delicious was found to vary with the set of other varieties (Fig. 4) in the orchard.

It became very apparent early in the survey and continued to be evident that the adjacent variety greatly affected the amount of apples on the Delicious trees (Fig. 5). The poor sets beside Duchess were not anticipated. Duchess pollen is known to set Delicious when applied manually. Until further evidence is available, it will be assumed that bees do not pass habitually between these varieties.

The sets beside Winesap were in the southern edge of the apple region. As this variety is reported to have non-functional pollen in the more northern latitudes the question arises as to whether some good



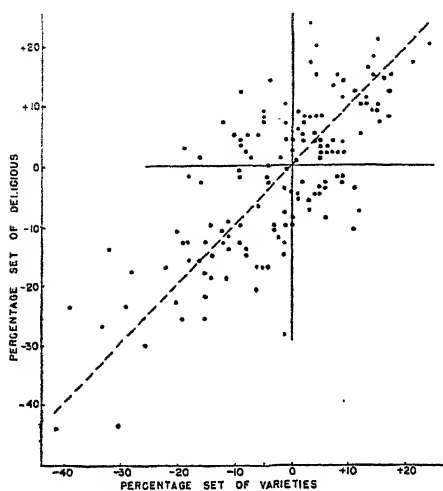


FIG. 4. Graph showing the relation of the setting of Delicious and other varieties in the same orchard (all percentages referred to the graph of Fig. 2). The vertical distribution about the broken line shows the range in Delicious setting due to differences in pollinating varieties, culture, and so on. The correlation coefficient is .765, showing that there is less than one chance in a hundred that the correlation is not significant.

pollen was produced this year by Winesap in the South.

Good crops were found beside Rome (and its red sports). The apparent efficiency of this variety (and Northwestern) in producing a set of Delicious is believed to be due to the late blossoming season. After the early varieties are through blossoming the bees work in the later Delicious blossoms and the Rome blossoms which are out at this late date.

The significant finding during the survey was the importance of proximity of pollen source to the setting of Delicious. No poor crops of Delicious were found when the adjacent variety had a high percentage set (provided of course that this variety would pollinate it).

In all of the very few cases where Delicious set well at a distance of four or five rows from a pollen source, the other varieties were overloaded to where thinning was necessary if apples of good size were to be harvested. In no case (166 plantings) were there better percentage sets at a distance from a pollen source than beside it. Some instances were found where there were no Delicious crops beside a good pollinating variety. Here the Delicious had not blossomed due to an off year following a heavy previous crop. The importance of distance from the pollen source is illustrated by a 25.5 lower percentage set on the third row (59 blocks) and a 32.8 lower set on the fifth row (30 blocks) away from the pollinating trees. Again, when the pollination conditions were poor, using poor setting of other varieties as an indicator, the sets averaged 23.8 per cent lower on the far sides of the trees which stood next to the pollinating variety. This condition has been previously reported (4).

The outside row where Delicious is planted on the edge of the orchard regularly had somewhat better sets, as if incoming bees had brought pollen from a distance.

One record of the effect of the distance from the bee hives was secured. Golden Delicious and Wealthy which overloaded near the hives

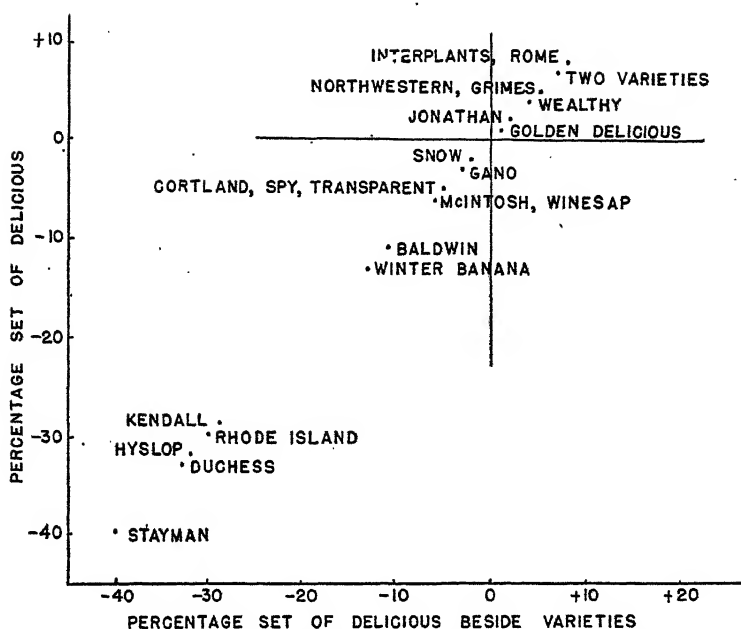


FIG. 5. This diagram shows the way Delicious was found to have set when growing beside different varieties.

had good crops 25 rows away. McIntosh was good 15 rows away, but poor 25 rows away and Delicious (interplanted with McIntosh) was poor less than 10 rows from the bees. This is assumed to be another evidence of the greater bee visitation needed to set Delicious than is required for most other varieties.

The reported poorer cropping of Delicious in recent years appears to be due largely to such items as the removal of fillers, the increase in amount of blossoms per acre with the aging of the trees and particularly to a general lack of interest in bees where such heavy-setting varieties as Duchess, Golden Delicious, Transparent, and Wealthy are grown. These greatly overload if enough bees are present to give a good set of even narrow blocks of Delicious.

No evidence of geographic effect was noted although areas as Door County, Wisconsin averaged poor sets and no poor sets were found in Northeastern New England and Nova Scotia. Some of the best as well as the poorest sets recorded were only 3 to 4 miles apart in Door County depending upon bee population. In New Hampshire all Delicious trees bore well. There this variety was planted only as a pollinizer and all trees are surrounded by trees of one or more varieties. In Nova Scotia it was found that it is the habit there for no variety to be planted more than two rows wide. Consequently no trees lack a nearby pollen source. It is in the Midwest and Southeast where planting habits result in blocks of several rows wide that dissatisfaction with Delicious setting is more pronounced.

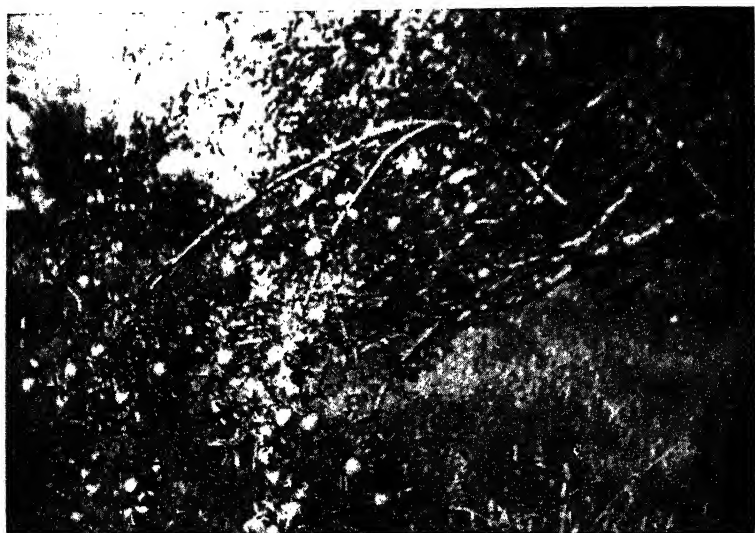


FIG. 6. Trees in poor vigor set well when well pollinated.

The role of tree vigor and nutrition in the setting of Delicious was found to be very interesting, but apparently less of a determined factor in the variable cropping of Delicious than was nearby pollen source. A number of good sets of this variety were found in neglected orchards where vigor was low or really missing (Fig. 6). As stated in the list of handicaps to the setting of Delicious, this variety has poor sets of pollinated fruits. Good sets are not produced by good growing conditions without a good pollen supply. Many orchards in fine vigor had poor sets. Delicious had relatively as good sets in poorly vegetative orchards as did other varieties. Actual percentage setting in 19 vigorously growing orchards was  $7.5 \pm .97$  per cent above normal (Fig. 2), and in 12 orchards with "starved" trees,  $3.0 \pm 2.07$  per cent below. The average difference of 10.5 per cent in set between the best and the poorest orchards visited may be important, but it is still a relatively small item in accounting for the near crop failures often seen in Delicious. Thinning was necessary in those more vigorous orchards where there was abundant pollination (Fig. 7).

One item upon which data were collected was the relation of branch vigor to blossoming and set and another was the role of spur vigor to fruiting this season.

Fig. 8 shows the almost direct relation between the length of terminal growth on individual branches on a fruiting tree and the percentage of blossoms on its growing points (older spurs and new lateral spurs) (7). By comparing this situation with the relation of blossoming to set (Fig. 2), it is very clear that good fruiting of Delicious is much dependent upon pruning from the tree those branches with less terminal growth than about 4 inches. This would have the treble advantage of giving better percentage sets, larger fruits and repeated

blossoming. This type of pruning has the effect of maintaining the tree in the same growth condition that prevails during the first few cropping seasons of the young tree.

Several orchards were visited where the reason for poor cropping was an over-vegetative condition. The trees had grown too much to produce good numbers of blossoms.

Observation of the relation of spur vigor to cropping this year proved to be very interesting. As with other varieties, the fruits are commonly borne on the more vigorous spurs (1). It was found that this was not always the case this year where frost injury or poor pollination conditions were prominent factors in the cropping. Fig. 9 shows typical spur development as measured by leaf numbers, of Delicious, McIntosh and Wealthy this year. The effect of pruning weak branches from Delicious trees upon increased spur vigor is also diagrammed. Particular attention is called to the average lengths of the spur classes which have been described by Blake. For classes 1 to 4 (9 to 6 leaves per spur) the average lengths were respectively: 14.5, 8.4, 5.5, and 3.2 mm. With these figures in mind the actual lengths of spurs with fruits in typically different orchards become particularly interesting (Table I).



FIG. 7. Vigorous trees with plenty of pollen needed thinning.

TABLE I—LENGTH OF DELICIOUS SPURS\* WHICH BLOSSOMED AND WHICH HELD OR DROPPED THEIR BLOSSOMS (AUGUST, 1946)

Orchard Crop Condition	Average Spur Lengths (Mm)**	
	With Fruits	Without Fruits
Good set, good pollination.....	9.7	5.4
Light crop, very poor pollination.....	5.4	8.1
Poor set, distant from bees.....	7.5	9.7
Good crop, frost injury†.....	7.8	7.8
Same, including axillary fruits.....	6.1	4.9
Good crop, superior pollination.....	11.0	5.3

\*Growth less than 20 mm or approximately  $\frac{3}{4}$  inch in length.

\*\*Ten mm equal about  $\frac{3}{8}$  inch.

†From 44 to 56 per cent crop on terminals, that is on growths over 2 inches long and as much as 8 per cent of the crop from axillary blossoms.

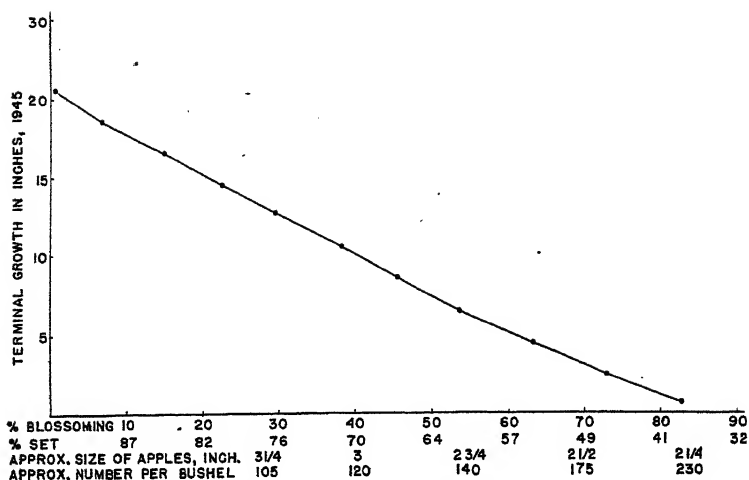


FIG. 8. Relation of length of terminal growth of branches and blossoming, fruit set and apple size, 1946.

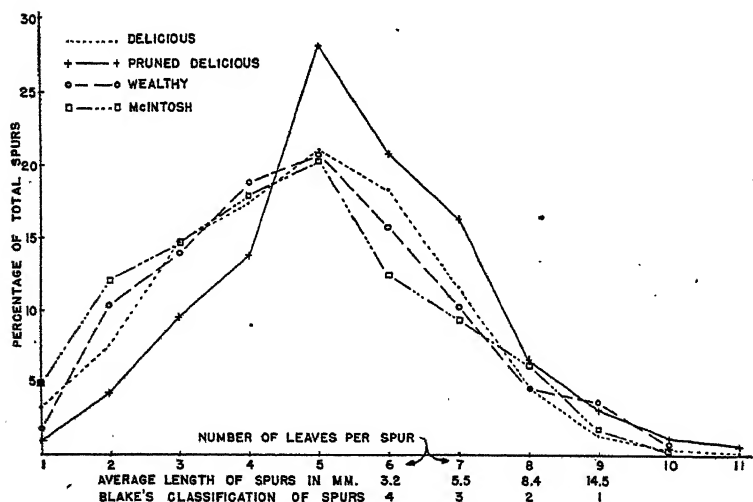


FIG. 9. Typical spur vigor of Delicious, McIntosh and Wealthy, 1946, as indicated by leaf numbers.

The very obvious fact of Table I is that in orchards having poor pollination the apples were borne on the weaker spurs rather than the more vigorous ones. This is because the late-blossoming, weaker spurs were the ones upon which the blossoms became pollinated towards the close of the blossoming season. On trees having good pollination, the fruits were on the longer spurs as is to be expected (1).

On a basis of this year's observations, a solution to the problem of getting a good set of Delicious appears to be a matter of a nearby pollen source. In old established blocks of Delicious a graft could be set into each tree or every other tree. With new plantings, have Delicious no farther than one tree away from pollen; that is, plantings of not more than two rows wide.

It seems inadvisable to increase the bee population to a point sufficient to insure a set of Delicious. This procedure increases the set on other varieties to where thinning is needed and biennial bearing accentuated. In cases where Delicious set at a distance of a few rows from the pollen source, the grower had provided as many as two hives of bees per acre or there were large natural populations, especially of bumblebees.

This year, "pollination weather" was generally favorable over most of the East, and a "good Delicious year" resulted where abundant pollen was available. What the set situation will be found to be in a season when there is a very limited pollination period must await the collecting of data under such a set of weather conditions.

#### SUMMARY

Data collected in 166 blocks of Delicious from Arkansas and Minnesota to Virginia and Nova Scotia gave a consistent record of good sets of this variety when a source of compatible pollen was adjacent to the Delicious (or its red sports). For example, the grower with a reputation as a successful producer of Delicious in one state has grafts of McIntosh or Golden Delicious in each tree.

Good sets of Delicious were consistently found beside late blossoming varieties as Rome (and its red sports) and Northwestern Greening. Varieties with late axillary blossoms as Golden Delicious and Wealthy seem to be practical sources of pollen.

It appears to be unsafe to have Delicious more than one row away from a good pollen source.

Good sets of Delicious were not well associated with tree vigor as some good crops were found on neglected trees in very poor growth condition and many well cared-for orchards with trees of proper vigor for good cropping bore very disappointingly few fruits.

Spur vigor was associated with good setting only on trees with very good pollination conditions. Crops were borne on the weaker spurs when poor pollination conditions were found. This is because these spurs blossom later and apparently bees pollinate these if another late source of pollen is present as Rome or Northwestern.

Also, trees which had their early blossoms frozen off bore their crops on the smaller, late-blossoming spurs.

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## The "Spot" Disease of Northern Spy Apples

By R. M. SMOCK, *Cornell University, Ithaca, N. Y.*

NORTHERN Spy apples are subject to a spot disease in cold storage in New York. Dr. L. J. Tyler of the Plant Pathology Department, at Cornell University made a survey of storage disorders in apples during the 1943-44 season (2). He reported that 40 of the 61 lots of Spies examined around New York State in cold storage had this disorder. In one lot inspected 47 per cent of the fruits were affected with this trouble. Tyler described the disease as follows: "the symptoms are in the form of circular to ovate brown, sharply sunken lesions which vary in diameter from the size of a small pencil point dot to slightly more than one-eighth inch. The lesions are usually located on the stem end and sides of the fruit and there may be 100 or more lesions per fruit." In unpublished work Tyler found that this disorder was not caused by a pathogen but seemed to be physiogenic in nature. The trouble should not be confused with *Alternaria* or *Phoma* decay spots, although the symptoms are somewhat similar (Fig. 1).

This study was undertaken to determine some of the orchard and storage factors which might affect this disease.

### ORCHARD FACTORS

*Effect of Ringing, Limb Shading, and Fruit Shading:*—In mid-July of 1944 individual large scaffold limbs of three Northern Spy trees were ringed. Similar limbs were shaded with three thicknesses of cheesecloth. Similar limbs were also defoliated on each tree. On other limbs individual fruits were shaded with white waxed paper "caps." The apples were stored at 40 degrees F. The results appear in Table I.

It is apparent in Table I that ringing was the only treatment which increased the spotting of the fruit. The other differences were insignificant.

Since ringing was found to increase this disorder in the 1944-45 storage season, this treatment was repeated in July of 1946. It may be seen in Table I that ringing increased the trouble during this season also.

*Effect of Fruit Position in Tree:*—It had been observed that this trouble was much more prevalent on the red or blushed side of the fruits

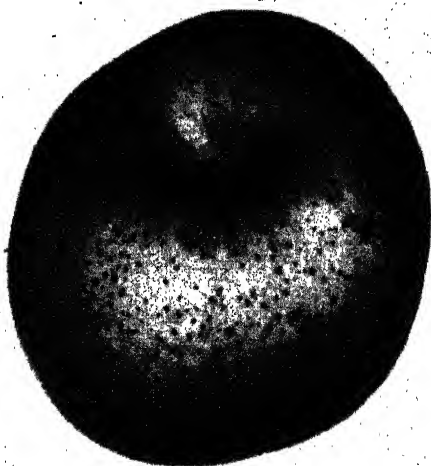


FIG. 1. Spy spot disease.



TABLE I—EFFECT OF RINGING, DEFOLIATION, LIMB AND FRUIT SHADING ON SPY DISEASE OF NORTHERN SPY

Tree No.	Treatment	1944-45	1946-47
		Per Cent Spy Spots Feb 20, 1945	Per Cent Spy Spots Feb 26, 1947
1	Untreated	1.53	0.0
1	Ringed	35.18	2.0
1	Defoliated	0.0	—
1	Limb shaded	0.0	—
1	Fruit Shaded	0.0	—
2	Untreated	2.08	0.0
2	Ringed	8.00	16.0
2	Defoliated	1.72	—
2	Limb shaded	1.72	—
2	Fruit Shaded	0.0	—
3	Untreated	0.0	0.0
3	Ringed	13.55	15.0
3	Defoliated	0.0	—
3	Limb shaded	0.0	—
3	Fruit shaded	0.0	—

than on the unblushed side. Hence bushel samples of fruit were harvested in 1944 from the inside and the outside (exposed) portions of two trees and stored at 40 degrees F until February 23, 1945. The results in Table II show that fruits from the exposed portions of the tree are much more subject to this trouble. These fruits, of course, had a higher red coloration than the shaded ones.

TABLE II—EFFECT OF FRUIT POSITION IN THE TREE ON SPY SPOT AFTER STORAGE

Tree No.	Position in Tree	Spy Spot (Per Cent)
1	Interior	2.70
1	Outer portion	32.14
2	Interior	3.74
2	Outer portion	29.36

*Effect of Fruit Maturity at Harvest Time:*—Bushel samples of apples were picked from the same trees on different dates in 1944 and 1946. The apples were stored at 40 degrees F in 1944 and 32 degrees F in 1946. The results in Table III indicate that the later picked apples are more subject to this disorder in storage.

#### STORAGE FACTORS

*Temperature:*—One bushel lots of Spy apples were stored at 32 degrees F and 40 degrees F during three seasons to determine the

TABLE III—EFFECT OF TIME OF PICKING ON SPY SPOT AFTER STORAGE

Harvest Date	1944-45 Per Cent Spy Spot	1946-47 Per Cent Spy Spot
Sep 22	0.0	—
Sep 29	0.0	—
Oct 6	0.0	0.0
Oct 12	0.83	0.0
Oct 20	8.69	0.0
Oct 30	33.04	2.0

effect of these two temperatures on Spy spot. Table IV shows that the trouble was more prevalent at the higher temperature two years out of three.

TABLE IV—EFFECT OF STORAGE TEMPERATURE ON SPY SPOT

Orchard No.	Storage Temperature (Degrees F)	Spy Spot (Per Cent)		
		1943-44	1944-45	1946-47
1	40	—	33.0	8.5
1	32	—	5.5	8.0
2	40	25.6	15.3	—
2	32	3.6	7.1	—

*Controlled Atmosphere Storage:*—Various carbon dioxide and oxygen combinations were used at both 32 degrees F and 40 degrees F to test their effect on Spy spot. The fruit was examined in March or April during the four year tests. Table V shows that with a low

TABLE V—EFFECT OF CONTROLLED ATMOSPHERE STORAGE ON SPY SPOT

Temperature (Degrees F)	CO <sub>2</sub> (Per Cent)	O <sub>2</sub> (Per Cent)	Firmness Lost During Storage (Pounds)	Spy Spot (Per Cent)
<i>1943-44</i>				
40	0	21(air)	4.5	25.6
40	5	15	4.0	11.7
40	10	2	1.3	0.0
<i>1944-45</i>				
32	0	21(air)	4.8	7.14
40	0	21(air)	7.5	15.30
40	5	10	5.2	13.20
40	5	2	0.8	0.0
40	10	2	0.0	0.0
<i>1945-46</i>				
40	0	21(air)	10.1	9.37
40	5	2	6.4	0.0
40	10	2	5.7	0.0
<i>1946-47</i>				
32	—	21 (air)	7.4	8.0
32	10	2	4.1*	0.0
40	0	21(air)	9.2	8.5
40	10	2	3.9	0.0

\*Severe "brown heart" damage here.

oxygen atmosphere (2 per cent) this trouble was entirely prevented at both 32 and 40 degrees F. Both 5 and 10 per cent of carbon dioxide at 40 degrees F prevented this disease when the oxygen level was at 2 per cent. When the oxygen level was as high as 10 to 15 per cent at 40 degrees F, there was a reduction in the disease but not control. It should be noted that 10 per cent carbon dioxide and 2 per cent oxygen at 32 degrees F, controlled the disease but resulted in severe brown heart damage. This is a low temperature-carbon dioxide injury. No such injury was noted at 40 degrees F.

Controlled atmosphere storage with either 5 or 10 per cent carbon dioxide and 2 per cent oxygen at 40 degrees F, not only controlled

Spy spot but materially lengthened the storage life of the fruit as compared to the common practice of storage in air at 32 degrees F.

*Carbon Dioxide Treatment:*—A 2-bushel lot of Spy apples was treated during the 1946-47 season with 50 per cent carbon dioxide for 6 days at 40 degrees F. They were subsequently held in air at 40 degrees F. The control apples were held continuously at 40 degrees F in air. On examination in early March it was found that the control apples had 8.5 per cent Spy spot and the treated apples had 2.0 per cent spot. This was a significant reduction in spotting, but the treatment would have no commercial usefulness because these apples were affected with internal carbon dioxide injury. Many areas within the flesh of the fruit were affected with brown, flaky, dead tissues. While lower concentrations of carbon dioxide might have resulted in less or no injury, it should be remembered that even this extreme treatment did not entirely control the trouble.

*Effect of Ripe Apple Vapors:*—It has been shown with the scald disease that the emanations from ripe apples (particularly of McIntosh) would increase scald intensity (1). A study was made of this point during the 1944-45 season at 40 degrees F in air storage in connection with Spy spot. The same technique was used as has been described previously (1). When the vapors of 2 bushels of Northern Spy apples in one chamber were aspirated continuously over 2 bushels of similar Spy apples in another chamber until February 26th there was 7.82 per cent of Spy spot. When the vapors of 2 bushels of very ripe McIntosh apples were aspirated over 2 bushels of Spies in another chamber there was 8.75 per cent Spy spot. Hence it would seem in this case, at least, that the vapors of McIntosh did not increase the spotting of Spies.

In another experiment 2 bushel lots of Spies were stored at 32 to 34 degrees F in a mixed variety room. A second lot of Spies was held at 34 degrees F in a commercial storage room with mixed varieties but the air was purified with activated carbon (1). The apples were examined in April. The control had 7.14 per cent Spy spot and those in the "air purified" room had 7.69 per cent spot. This experiment would further indicate that the Spy spot disease is not related to scald since scald can be reduced or controlled by air purification (1).

## DISCUSSION

The Spy spot disease of apples is a physiological disorder occurring in storage on the red or blushed portion of the fruit. It seldom appears on the yellow portion of the fruit. It developed in storage to a greater extent on apples picked from the outer or exposed parts of the tree. It was worse on late than early picked fruits. Ringing increased the amount of the disease. Exposed fruits (from the outer portion of the tree), late picked fruits, and ringed fruits are usually redder than other fruits. All of these factors indicate that this disease is associated in some way with the red coloration of the fruit.

The disease developed to a greater extent at 40 degrees F than at 32 degrees F two years out of three.

The trouble does not seem to be related to apple volatiles as is the apple scald disease since ripe apple vapors did not increase it in storage. Nor did air purification reduce its intensity.

This disorder probably resembles Jonathan spot more than any other storage trouble. Yet the symptoms are not identical with Jonathan spot.

Carbon dioxide treatment (50 per cent carbon dioxide for 6 days) reduced the amount of this disease but resulted in severe carbon dioxide injury.

The only practical approach to control of this trouble arising from this study was controlled atmosphere storage. Either 5 or 10 per cent carbon dioxide with 2 per cent oxygen at 40 degrees F not only controlled the trouble but added considerably to the storage life of the fruit (as compared to the usual practice of storage in air at 32 degrees F). The use of 10 per cent of carbon dioxide and 2 per cent oxygen at 32 degrees F controlled the trouble but considerable brown heart (a low temperature—carbon dioxide disorder) was experienced.

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## The Influence of Rootstocks on the Occurrence and Severity of Bacterial Canker, *Pseudomonas Cerasi*, of Stone Fruits

By LEONARD H. DAY, *University of California, Davis, Calif.*

BACTERIAL canker, more commonly known to Pacific Coast fruit growers as bacterial gummosis and sour sap, has apparently been present in parts of California for over 50 years. My observations and experimental work with it began in 1908 in San Benito County, California, and growers reported that it had then been present there for many years. It appeared to be the same gummosis trouble which I saw on cherries in Oregon in 1910, the causal organism of which Griffin (1) named *Pseudomonas cerasus*. In 1914 (2) I successfully transferred the disease from one apricot tree to another. In the spring of 1919, Dr. J. T. Barrett reported the organism in the apricot orchards with which I had been working in San Benito County to be the same as he had found in apricot trees in Riverside and Kings Counties.

The most conspicuous phase of the disease is the development of bark cankers on scaffold branches or on the trunks above the graft unions, with or without copious exudation of gum. When a branch or trunk is completely girdled by the disease the parts above soon wilt and die. That type of the disease without copious gumming the growers commonly call sour sap. The cankers do not progress downward more than an inch or two below ground, and the infections seldom begin in the rootstock. In case of susceptible rootstocks, and with the graft union well above ground, the infections occasionally begin below the graft union.

In 1918, Barrett (3) reported the bacterial nature of gummosis in apricot in Riverside and Kings Counties. The following spring I observed that in Kings County it was largely confined to apricot on myrobalan roots and that the disease was much less injurious when the apricots were on peach roots, and furthermore that the frequency of infections on apricots on apricot roots was intermediate between those on myrobalan and on peach. One affected orchard had trees on all three roots under identical soil conditions. Since that year this same order of frequency of infection of apricot trees on the three stocks has been observed many times throughout the Sacramento and San Joaquin Valleys. In San Benito County it was observed to be more common on myrobalan-rooted trees than on those on apricot root but there were no apricot trees on peach roots for comparison. The disease occasionally affects French prune trees and many times it has been observed that whenever they are on both myrobalan and peach roots under identical soil conditions it is less serious on the peach-rooted trees.

In 1919, I observed what appeared to be the same disease on plum and cherry trees in Placer County, California, where the disease periodically becomes active and kills many thousands of trees. Later work by Goldsworthy and Smith (4) demonstrated the cause to be

bacterial, and in 1933 Wilson (5) reported the causal organism in that area to be *Pseudomonas cerasi*. During experimental control work on cankers of the disease beginning in 1928, in Placer County, I noted that the disease on plum trees was much less common when on peach roots, and particularly so when the plums were top-worked high upon peach varieties. Several growers who noted that certain peach varieties were seldom injured by the disease have planted these varieties on peach seedling roots and after they had grown in the orchard 3 or 4 years, topworked them to the desired plum varieties. Salwey is the peach variety most favored for this work. Some of the trees on Salwey are now up to 16 years of age and have been practically free from the disease. In the fruit districts of Placer County are many instances of peach orchards that were top-worked to plums many years ago and the disease is conspicuously less severe in these than in adjacent plum trees on myrobalan roots.

Peach seedlings are usually more resistant than myrobalan seedlings and Marianna plum but are not uniformly free from the disease. Susceptible plum varieties topworked in the orchard upon myrobalan seedlings and upon Marianna plum are perhaps not more free from the disease than are those worked at the ground on these same stocks. Santa Rosa, Duarte and President plums are particularly susceptible to the disease, whereas Kelsey and Beauty are seldom injured, regardless of the rootstocks upon which they are growing.

In 1933, it was noted in orchards belong to the Penryn Fruit Company, Placer County, that Santa Rosa and Duarte plums originally planted on peach roots, but which had grown strong plum scion roots above the unions, were more susceptible to bacterial canker (in the scaffolds and trunks) than were those which remained entirely on peach roots. In the spring of 1935, I furnished this grower with 30 Santa Rosa trees grown on their own roots by cuttings and by layering. These were used as replants in a Santa Rosa orchard on myrobalan roots in which the disease had been killing trees over a period of many years and in which in 1932 replanting with Santa Rosa on peach roots was commenced. The own-rooted Santa Rosa trees grew well but were very subject to bacterial canker, and by the end of the spring of 1938 all of them had been killed by the disease, whereas only a small number of the replants on peach roots had been injured.

In the spring of 1938, one grower cut off the scion roots of Santa Rosa and Duarte trees which were originally planted on peach roots. This treatment has apparently prevented further serious injury though the disease is continuing to kill trees in adjacent orchards. This grower reports that scion-rooted Santa Rosa trees are not as fruitful as those remaining on peach roots, and that the fruit is not so large. Several other growers are so convinced of the good results accruing from cutting off scion roots in this orchard that they are adopting the practice with trees in which the scion roots have not become too large.

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## Internal Temperatures of Plants

By RICHARD HOPP, *University of New Hampshire,  
Durham, N. H.*

WHEN speaking of the effects of temperature on plants or plant growth we are accustomed to using air temperature as a criterion, temperatures which are measured with sheltered equipment, protected from sudden climatic changes and influences. The knowledge of internal temperatures of plants and plant parts, especially with vegetable crops, and their relation to the environment, is as yet rather limited. Since plants, unlike warm-blooded animals, have no mechanism for controlling their own temperature independent of the environment it is generally assumed that plants or plant parts have approximately the same temperature as their surroundings. Until recently it has not been possible to make accurate and continuous temperature recordings in localized areas of living tissue. With the perfection of thermo-electric equipment and the use of thermocouples connected with a potentiometer, studies in this field have become possible. Eggert (1) reported the installation of thermocouples for biological research.

Work in the Horticultural Department at the University of New Hampshire in recent years has been carried out on cambium temperatures of peach, apple and maple trees. Considerable differences in temperature between cambium and air were recorded during periods of sunshine, particularly on the south side of apple trees. This phase of the work was reported on by Latimer in a preceding paper (2).

As far as vegetables are concerned, preliminary work was conducted by the author early in 1946 under greenhouse conditions, using a Leeds and Northrup Micromax recorder with eight copper-constantan thermocouples. Beans, tomatoes and strawberries were used and it was noted that in day time during dull and cloudy weather the internal temperatures differed only slightly, if at all, from the temperature of the surrounding air; the plant parts being generally a few degrees warmer. At night the plant parts usually were cooler than the surrounding air, the differences amounting to as much as 4 degrees Fahrenheit, particularly during the 2 or 3 hours before dawn. Marked plus differences, however, were observed during periods of bright sunshine inside bean pods, tomatoes and strawberries. The most striking observation was the response of the growing bean pod to direct sunlight. Almost as soon as the sun hit it, the temperature inside the pod started to rise, reaching in a short time as much as 10 to 20 degrees F above the air temperature. In some extreme cases the temperature inside the bean pod was 24 degrees F higher. Conversely, the temperature differences diminished to the normal 2 or 3 degrees soon after the pod was no longer in the direct sunlight. Stem and petiole also showed higher temperatures, although the fluctuations were not as pronounced as with the pods. Strawberries and tomatoes showed similar responses.



These greenhouse observations led to the planning of more comprehensive studies outdoors during the past season, using several kinds of vegetables. Temperatures were measured inside fruiting organs, such as bean and pea pods, tomatoes, ears of corn, summer and winter squash, cucumbers; inside stems and petioles of various plants; inside heads of lettuce; and inside radish and turnip roots. Simultaneously continuous temperature records were taken of the environment including air, surface of the ground, and 4 inches deep in the soil.

In these outdoor studies substantially the same results were obtained as under greenhouse conditions, that is plant parts, particularly fruiting organs, warmed up considerably above air temperature when exposed to sunlight, with differences as high as 20 degrees F and more above air temperature being recorded. The following are a few examples of temperature differences observed:

Tomato (fruit)

106 degrees F, air 83 degrees F, difference 23 degrees F

Pea pod

96 degrees F, air 82 degrees F, difference 14 degrees F

Winter squash

96 degrees F, air 75 degrees F, difference 21 degrees F

Summer squash

87 degrees F, air 66 degrees F, difference 21 degrees F

Differences in temperature of opposite sides of plant parts were observed, the side exposed to the sun being generally 5 to 7 degrees F warmer than the off side. For example, the temperature inside a pea pod on the side exposed to the sun registered 87 degrees F, and on the side away from the sun 82 degrees F. Similarly, the petiole of a squash leaf showed a temperature of 91 degrees F on the exposed side and 83 degrees F on the shaded side when the air temperature was 81 degrees F.

Temperature changes inside roots of radish and turnip, measured at soil level, are less affected by fluctuations of the air temperature but rather by those of the soil.

Temperatures of head lettuce were recorded as an example of a compact leafy structure. The temperature inside the headed lettuce remained consistently below that of the air with differences up to 8 to 10 degrees F. When the air temperature was 83 degrees F, for example, the temperature inside the lettuce was 77 degrees F while a tomato growing adjacent to it registered 106 degrees F.

The rate of warming up or cooling off varies in the fruits of different plants. The internal temperature of bean pods, pea pods, and ears of corn increases more rapidly than that of cucumber or squash when exposed to the sun. Conversely, a fruit such as squash will retain heat considerably longer and therefore cools more slowly than the air. Its internal temperature does not drop to air temperature until the following morning, about 6 a. m., at a time when the air begins to warm up again; consequently, the squash may stay cooler than the air for a few hours.

More detailed data of some typical outdoor observations are given in Tables I to III.

The obvious effect of direct sunlight on internal plant temperatures has since led to experiments in which plants were illuminated with light from different sources: ordinary electric bulbs, ultraviolet light,

TABLE I—TEMPERATURE INSIDE RIPE TOMATO COMPARED WITH AIR TEMPERATURE (DEGREES F)

Sep 7, 1946	Tomato	Air	Difference
6 a m.....	50	53	-3
7 a m.....	52	54	-2
8 a m.....	58	56	2
9 a m.....	65	63	2
10 a m*	78	70	8
11 a m*	90	76	14
Noon*	97	80	17
1 p m*	99	81	18
2 p m*	97	83	14
3 p m*	93	82	11
4 p m.....	88	82	6
5 p m.....	82	81	1
6 p m.....	80	78	2

\*Sunshine.

TABLE II—TEMPERATURE INSIDE WINTER SQUASH (BUTTERCUP) COMPARED WITH AIR TEMPERATURE (DEGREES F)

Sep 4-5, 1946	Squash	Air	Difference
Noon.....	68	76	-8
12:30 p m.....	72	78	-6
1:00 p m.....	76	78	-2
1:30 p m.....	88	81	7
2:00 p m*	92	76	16
2:30 p m*	96	75	21
3:00 p m*	90	74	16
4:00 p m*	86	71	15
5:00 p m*	81	66	15
6:00 p m.....	75	64	11
9:00 p m.....	57	50	7
12:00 p m.....	50	46	4
3:00 a m.....	47	44	3
6:00 a m.....	46	44	2

\*Sunshine.

TABLE III—TEMPERATURE INSIDE RIPE TOMATO AND LETTUCE COMPARED WITH AIR TEMPERATURE (DEGREES F)

Sep 16-17, 1946	Tomato	Lettuce	Air	Difference	
				Tomato/Air	Lettuce/Air
Noon*.....	99	75	80	19	-5
1 p m*.....	106	77	83	23	-6
2 p m*.....	105	78	83	22	-5
3 p m.....	91	76	82	9	-6
4 p m.....	84	71	81	3	-10
5 p m.....	78	69	76	2	-7
6 p m.....	72	64	70	2	-6
7 p m.....	67	60	63	4	-3
8 p m.....	62	56	59	3	-3
9 p m.....	57	52	54	3	-2
10 p m.....	54	52	54	0	-2
11 p m.....	52	50	52	0	-2
12 p m.....	50	48	49	1	-1
3 a m.....	45	44	45	0	-1
6 a m.....	42	43	44	-2	-1

\*Sunshine.

and infrared light. Briefly, the results thus far show that increases in the internal temperature comparable to those resulting from direct sunlight are obtained by the use of infrared light. With a standard commercial 250 watt infrared bulb placed 2 feet from a tomato growing in the greenhouse the temperature of the tomato fruit was raised as much as 17 degrees above air temperature (Table IV and Fig. 1). This effect could be induced at night and at day time during dull, cloudy weather.

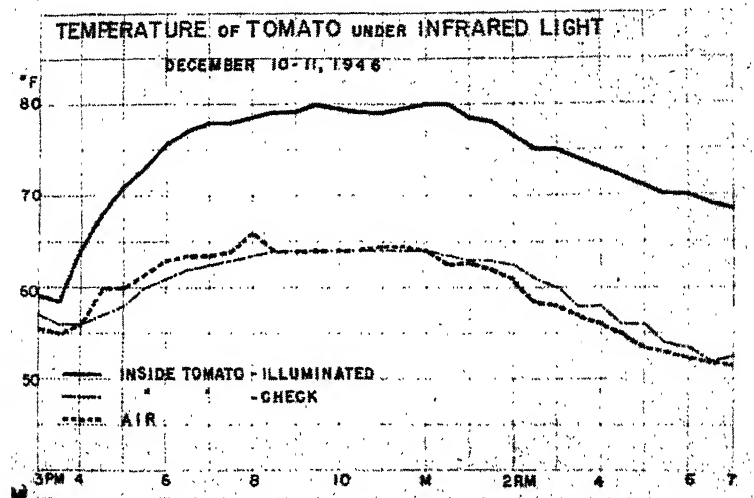


FIG. 1. Temperature of tomato under infrared light compared with air temperature (in greenhouse) December 10 to 11, 1946. Illumination started 3:30 P.M.

TABLE IV—TEMPERATURE INSIDE GREEN TOMATOES COMPARED WITH AIR TEMPERATURE (DEGREE F), 250 WATT INFRARED BULB, 24 INCHES FROM FRUIT

Dec 10-11, 1946	Illuminated Plant		Check Plant		Difference Between	
	Tomato (1)	Air (2)	Tomato (3)	Air (4)	Column 1 and 2	Column 1 and 4
3:30 p.m. ....	58.5	57.0	56.0	55.0	1.5	2.5
Light turned on:						
4:00 p.m. ....	64.0	58.0	56.0	56.0	6.0	8.0
5:00 p.m. ....	71.0	64.0	58.0	60.0	7.0	11.0
6:00 p.m. ....	75.5	66.0	61.0	63.0	9.5	12.5
7:00 p.m. ....	78.0	65.0	62.5	63.5	13.0	14.5
8:00 p.m. ....	78.5	68.0	63.5	66.0	10.5	12.5
9:00 p.m. ....	79.0	66.0	64.0	64.0	13.0	15.0
10:00 p.m. ....	79.5	66.0	64.0	64.0	13.5	15.5
11:00 p.m. ....	79.0	66.5	64.0	64.5	13.5	14.5
12:00 p.m. ....	80.0	65.5	64.0	64.0	14.5	16.0
1:00 a.m. ....	78.5	64.0	63.0	63.0	14.5	15.5
2:00 a.m. ....	76.5	62.5	62.5	61.0	14.0	15.5
3:00 a.m. ....	75.0	61.0	60.0	58.0	14.0	17.0
4:00 a.m. ....	73.0	58.0	58.0	56.0	15.0	17.0
5:00 a.m. ....	71.0	57.0	56.0	53.5	14.0	17.5
6:00 a.m. ....	70.0	55.0	53.5	52.5	15.0	17.5

During one night in which the air temperature outdoors went as low as 23 degrees F, a tomato was kept from freezing with a 250 watt infrared bulb. During that night the temperature inside the illuminated fruit did not go below 40 degrees F (Table V and Fig. 2).

TABLE V—TEMPERATURE INSIDE GREEN TOMATOES COMPARED WITH AIR TEMPERATURE (DEGREE F), 250 WATT INFRARED BULB, 12 INCHES FROM FRUIT; OUTDOORS

Dec 13-14, 1946	Illuminated Plant		Check Plant		Difference Between	
	Tomato (1)	Air (2)	Tomato (3)	Air (4)	Column 1 and 2	Column 1 and 4
4:00 p m.....	42.0	41.0	42.0	39.0	1.0	3.0
Light turned on 4:15 p m						
5:00 p m.....	44.5	38.0	36.5	36.5	6.5	8.0
6:00 p m.....	45.0	37.0	34.5	35.0	8.0	10.0
7:00 p m.....	45.0	35.0	33.0	33.5	10.0	11.5
8:00 p m.....	42.0	34.5	32.0	32.0	7.5	10.0
9:00 p m.....	42.5	33.5	31.0	31.0	9.0	11.5
10:00 p m.....	41.5	32.0	30.5	29.0	9.5	12.5
11:00 p m.....	41.0	32.0	31.0	29.0	9.0	12.0
12:00 p m.....	45.0	31.5	31.0	27.0	13.5	18.0
1:00 a m.....	44.5	31.0	30.0	27.0	14.5	17.5
2:00 a m.....	46.0	32.0	30.0	26.0	14.0	20.0
3:00 a m.....	48.0	31.0	30.0	26.5	17.0	21.5
4:00 a m.....	41.5	30.0	30.0	25.5	11.5	16.0
5:00 a m.....	41.0	30.0	29.0	25.0	11.0	16.0
5:30 a m.....	41.0	28.0	29.0	24.5	13.0	16.5
6:00 a m.....	42.5	29.0	29.0	24.0	13.5	18.5
6:30 a m.....	44.0	29.0	29.0	25.0	15.0	19.0
7:00 a m.....	45.0	30.5	29.0	25.0	14.5	20.0
7:30 a m.....	44.0	27.5	28.0	23.0	16.5	21.0
8:00 a m.....	44.0	30.0	27.0	25.0	14.0	19.0

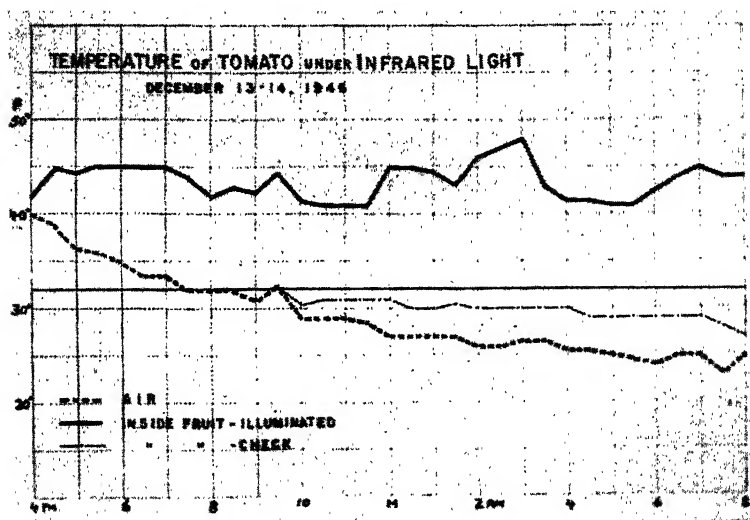


FIG. 2. Temperature of tomato under infrared light compared with air temperature (outdoors), December 13 to 14, 1946. Air temperature during the night went down to 23 degrees F, tomato remained above 40 degrees F.

These are some of the observations to date. It appears that our conception of plant temperature in relation to the environment may have to undergo some revision. Cells or tissues have their own temperature which may be different from the air temperature during the hours of sunshine. On sunny days, weather station records tell us little about the actual temperature conditions under which plant parts function. When a tomato plant grows in soil of 70 degrees F while the air is 80 degrees F, the ground surface 90 degrees F and the temperature inside the ripe tomato 100 degrees F, it can hardly be said that the internal temperature of the plant is "approximately the same as the temperature of its surroundings".

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## Some Requirements of McIntosh Apples in Controlled Atmosphere Storage

By R. M. SMOCK, *Cornell University, Ithaca, N. Y.*

THE general requirements of New York apples to be stored in controlled atmosphere storage have been described (1, 2, 3, 7). The technique has been adopted commercially on a limited scale in New York and New England for McIntosh apples. Since the procedure of controlled atmosphere storage has been tested over a 9-year period it seems worthwhile to summarize the comparative value of this technique as compared to storage in air at 32 degrees F. Since the adoption of this practice commercially, several questions have arisen which were not answered by the earlier work.

One question which has arisen was that of the exact oxygen, carbon dioxide, and temperature requirements for McIntosh. Was the recommendation of 5 per cent carbon dioxide and 2 per cent oxygen at 40 degrees F the "last word" for this variety. Another question which arose was: "could decay be controlled by using this procedure?" Another question was "how may scald best be controlled in this type of storage?" Still another question was "what is the effect of delayed storage at 32 degrees F before sealing up the room and starting controlled atmosphere storage?"

### METHODS

The methods used in conducting these experiments were essentially those reported in earlier publications (1, 2, 3, 7). Where modifications of these methods were employed they are noted in the text.

Two-bushel lots of apples were used for each treatment.

### COMPARATIVE VALUE OF CONTROLLED ATMOSPHERE STORAGE VERSUS COLD STORAGE IN AIR AT 32 DEGREES FOR MCINTOSH

Table I indicates the relative value of storing McIntosh apples in 5 per cent carbon dioxide and 2 per cent oxygen at 40 degrees over a period of 9 years. The expression "days storage life added" is only an approximation. Its method of calculation has already been described (4). It will be noted in Table I that controlled atmosphere storage definitely slowed down firmness losses in storage when compared with ordinary cold storage at 32 degrees F. It will also be observed that fruit response was better some years than others. Table I also shows that controlled atmosphere storage controlled the brown core disease in all years but one (6).

### ATMOSPHERIC AND TEMPERATURE REQUIREMENTS OF MCINTOSH IN CONTROLLED ATMOSPHERE STORAGE

As a result of earlier studies (1, 2, 3, 5, 7) it was found that an atmosphere of 5 per cent carbon dioxide and 2 per cent oxygen at a temperature of 40 degrees F seemed optimum for McIntosh. The

TABLE I—NINE YEARS' RESULTS WITH MCINTOSH APPLES IN CONTROLLED ATMOSPHERES AT 40 DEGREES COMPARED WITH STORAGE IN AIR AT 32 DEGREES F

Temp (Degrees F)	CO <sub>2</sub> (Per Cent)	O <sub>2</sub> (Per Cent)	Firmness Lost During Storage (Pounds)	Brown Core (Per Cent)	Days Storage Life Added*
<i>March 1, 1939†</i>					
32	—	Air	5.5	55	—
40	5	2	3.0	0	80
<i>May 1, 1940</i>					
32	—	Air	5.8	0	—
40	5	2	4.9	0	42
<i>March 9, 1941</i>					
32	—	Air	4.0	53	—
40	5	2	1.9	10	83
<i>May 1, 1942</i>					
32	—	Air	5.5	30	—
40	5	2	2.9	0	96
<i>May 5, 1943</i>					
32	—	Air	6.7	73	—
40	5	2	4.4	0	74
<i>March 7, 1944</i>					
32	—	Air	5.8	37	—
40	5	2	3.4	0	65
<i>April 10, 1945</i>					
32	—	Air	6.3	52	—
40	5	2	1.2	0	150
<i>May 1, 1946</i>					
32	—	Air	7.4	66	—
40	5	2	5.7	0	48
<i>March 3, 1947</i>					
32	—	Air	6.6	40	—
40	5	3	2.8	0	81

\*Days storage life added as a result of controlled atmosphere storage when compared to air in 32 degrees F.

†Date out of storage.

question has been raised however whether all possibilities had been explored. Hence, further trials have been made on various carbon dioxide and oxygen mixtures at both 32 degrees and 40 degrees F. Tables II and III show the combinations used and the results obtained with McIntosh.

These tables show that while this variety may be kept firmer in controlled atmosphere storage at 32 than at 40 degrees that brown core and internal browning were experienced at the lower temperatures. Quality was also poor in the fruits stored at 32 degrees in various carbon dioxide and oxygen mixtures.

The effects of carbon dioxide level on carbon dioxide injury are apparent in Table II. Injury was greater at 32 than at 40 degrees F and increased in amount with increasing carbon dioxide percentages.

Both Tables II and III suggest that no improvement can be sug-

TABLE II—ATMOSPHERIC AND TEMPERATURE REQUIREMENTS OF MCINTOSH APPLES IN CONTROLLED ATMOSPHERE STORAGE 1944-45

Temp. (Degrees F)	CO <sub>2</sub> (Per Cent)	O <sub>2</sub> (Per Cent)	Firm- ness Lost in Storage (Pounds)	CO <sub>2</sub> Injury (Per Cent)	Brown Core (Per Cent)	Brown Heart (Per Cent)	Eating Quality	Days Storage Life Added*
<i>April 10, 1945</i>								
32	—	Air	6.3	0.0	52	0	Poor	—
32	5	2	0.6	1.0	6	29	Very poor	0
32	10	2	1.1	73.0	14	61	Very poor	0
40	—	Air	9.5	0.0	0	0	Mealy	0
40	5	10	7.3	0.5	0	0	Poor	0
40	10	10	6.7	5.0	0	0	Poor	0
40	14	10	7.8	36.0	32	49	Very poor	0
40	5	2	1.2	2.0	0	0	Good	150
40	10	2	1.4	5.0	0	11	Good	140

\*Compared to 32 degrees F air.

TABLE III—ATMOSPHERIC AND TEMPERATURE REQUIREMENTS OF MCINTOSH APPLES IN CONTROLLED ATMOSPHERE STORAGE 1946-47

Temp. (Degrees F)	CO <sub>2</sub> (Per Cent)	O <sub>2</sub> (Per Cent)	Firmness Lost in Storage (Pounds)	Brown Core (Per Cent)	Brown Heart (Per Cent)	Eating Quality	Days Storage Life Added
<i>March 3, 1947</i>							
32	—	Air	5.7	40	0	Fair	0
32	2	3	2.6	0	34	Poor	0
32	5	3	3.8	4	42	Poor	0
40	—	Air	6.6	0	0	Mealy	0
40	2	3	3.6	0	0	Excellent	51
40	5	3	2.8	0	0	Excellent	81

gested at the present time over the former recommendation of 5 per cent carbon dioxide and 2 to 3 per cent oxygen at 40 degrees F.

On the basis of commercial results it is suggested that the oxygen level not be allowed to go below 2.5 per cent. In some of the larger commercial controlled atmosphere storage rooms, some low oxygen injury has been apparent on the more mature fruits. This seems to have resulted from poor circulation of the atmosphere in some parts of the room. This factor became critical when the operator was operating at 1.5 to 2.0 per cent oxygen levels. As a safety measure it would seem wiser then to operate with 2.5 to 3.0 per cent oxygen in commercial practice.

Although the results are not presented here, experiments were conducted during the 1941-42 and 1942-43 season in which 5 per cent carbon dioxide was used for 1, 2, 3, and 4 months and then raised to 10 per cent. These treatments were compared to continuous exposure to 5 per cent carbon dioxide. The oxygen level was 2 per cent in all cases. There seemed to be no advantage in any of these treatments over continuous operation at 5 per cent carbon dioxide.

Two points, at least, need further study in this connection. In some years 5 per cent or more of carbon dioxide injury has been noted on the less mature fruits held in 5 per cent carbon dioxide. A study



should be made of the possibility of using a lower carbon dioxide level (such as 2 or 3 per cent) for 1, 2, 3, and 4 months and then allowing the level to rise to 5 per cent in an attempt to escape the carbon dioxide injury that occurs in occasional years.

All of the Cornell studies to date have included temperatures of 32, 36, and 40 degrees F in controlled atmosphere storage. This study and a previous study (2) have shown that 32 and 36 degrees F were too low. The question remains as to how close to 36 degrees F one can come without any undesirable effects. If a temperature of 38 degrees F could be employed safely, it should result in longer keeping than at 40 degrees F.

#### EFFECT OF DELAY IN STORAGE

The question has arisen commercially as to the loss in benefit that might occur if apples were held after picking in 32 degrees F air for 1 or 2 months before controlled atmosphere storage was started. Table IV shows that even a delay of 1 month at 32 degrees F in air makes a

TABLE IV—EFFECT OF DELAY IN STORAGE AT 32 DEGREES F IN AIR PRIOR TO STORAGE IN 5 PER CENT CARBON DIOXIDE AND 2 PER CENT AT 40 DEGREES F (EXAMINED APRIL 13, 1943)

Treatment	Firmness Lost in Storage (Pounds)	Days Storage Life Added*
Immediate storage in controlled atmospheres.....	1.4	130
Delay of 1 month at 32 degrees in air.....	3.4	25
Delay of 2 months at 32 degrees in air.....	3.7	5
32 degrees air continuously.....	3.9	—

\*Days storage life added with controlled atmosphere storage when compared to storage in 32 degrees F air.

significant difference in the keeping quality of controlled atmosphere McIntosh. During the 1947-48 season delays of 1, 2, and 3 weeks are being studied.

#### EFFECT OF ROUGH HANDLING

The question has arisen as to the effect of controlled atmosphere storage on decay of fruit with skin punctures. A study was made of a lot of McIntosh that had suffered some hail injury. This hail-damaged fruit is usually quite subject to decay. In addition, half of the fruit was given one skin puncture per fruit with a sharp instrument. This fruit was then stored in 32 degrees air and in 5 per cent carbon dioxide with 2 per cent oxygen at 40 degrees F. Table V indicates that this

TABLE V—EFFECT OF INTERNATIONAL SKIN PUNCTURES ON DECAY OF MCINTOSH (EXAMINED MAY 1, 1946)

Treatment	Storage Treatment	Decay (Per Cent)
Normal.....	32 degrees air	16.9
Punctured.....	32 degrees air	100.0
Normal.....	40 degrees, 5 per cent CO <sub>2</sub> —2 per cent O <sub>2</sub>	11.1
Punctured.....	50 degrees, 5 per cent CO <sub>2</sub> —2 per cent O <sub>2</sub>	73.97

hail-damaged fruit was quite subject to decay even when not punctured intentionally. The skin puncturing did greatly increase the decay but the increase was less in controlled atmosphere storage than in ordinary cold storage. This study would suggest that though controlled atmosphere storage may reduce the amount of decay during storage, fruits may nevertheless decay in such storage when they have skin punctures.

#### SOME FACTORS IN CONTROLLED ATMOSPHERE STORAGE AFFECTING THE SCALD DISEASE

*Effect of Rate of Oxygen Decrease:*—It is usually stated that scald is worse in controlled atmosphere storage on a given variety than in ordinary cold storage. This may or may not be true. One of the factors determining the intensity of scald during storage in controlled atmospheres seems to be the rate at which oxygen drops from the normal of 21 per cent (in air) to 2 per cent. In some preliminary work with Rhode Island Greening it was shown that scald after storage was 46.29 per cent when the oxygen was dropped to 2 per cent within 1 week. When it was dropped to 2 per cent over a period of 4 weeks there was 98.44 per cent scald. With this point in mind an experiment was set up with McIntosh which were to be held in 5 per cent carbon dioxide and 2 per cent oxygen at 40 degrees.

In one gas-tight 55-gallon capacity chamber 2 bushels of McIntosh were placed. In a second chamber of the same size  $3\frac{1}{2}$  bushels were placed. Oxygen dropped to 2 per cent within about 2 weeks in the latter chamber and it required over 4 weeks to drop to 2 per cent in the first chamber. After storage (March 3, 1947) there was 50 per cent scald on the McIntosh apples with the 4 weeks oxygen drop to 2 per cent. There was 1.0 per cent scald on the apples with the 2 week drop to 2 per cent. This emphasizes the necessity of having a rapid oxygen drop in controlled atmosphere storage. This may be accomplished when the room is gas tight and when it is filled to capacity with fruit.

*Effect of Air Purification in Controlled Atmospheres:*—The possibility of using air purification with activated carbon for scald control has been outlined in detail in another publication (6). An experiment was set up during the 1946-47 season to check on previous results with this method of scald control. Two bushels of McIntosh were stored in each of two 55-gallon capacity chambers. The atmosphere of one was circulated through 80 grams of activated coconut shell carbon. The atmosphere of the other was circulated, but no carbon was used. The control fruit when examined on March 3, 1947 had 28.2 per cent scald. The fruit treated with air purification had only 1.7 per cent scald.

Air purification would seem to be the answer to the scald problem in controlled atmosphere storage. It is cheaper to use than oiled paper. Only one failure has been experienced with this procedure in commercial controlled atmosphere storage. In this particular case the oxygen drop was very slow and never dropped below 10 per cent.

## SUMMARY

The comparative value of controlled atmosphere storage at 40 degrees versus storage in air at 32 degrees F has been summarized for a 9-year period for New York McIntosh.

Temperature and atmosphere requirements of McIntosh have been explored further. The combination of 5 per cent carbon dioxide and 2 to 3 per cent oxygen at 40 degrees F still seems to be the optimum of all those studied.

The controlled atmosphere storage should be sealed up as soon as possible. A delay of 1 month at 32 degrees F in air had a marked effect in lessening the value of controlled atmospheres.

While controlled atmosphere storage may reduce decay on fruits with skin punctures it will certainly not control it.

The more rapidly the oxygen level drops in controlled atmosphere storage, the less will be the scald. This emphasizes the need of full and gas tight rooms.

Scald can be satisfactorily prevented in controlled atmosphere storage by means of air purification with activated coconut shell carbon.

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## Effect of Frequency and Method of Cultivation on the Growth of One-Year-Old Tung Trees

By MATTHEW DROSDOFF, ELWOOD G. FISHER, and JUDSON H. LASSITER, *U. S. Department of Agriculture, Gainesville, Fla.*

IN a previous study (1) with transplanted 1-year old tung trees growing on Norfolk fine sand, it was found that frequent spading throughout most of the growing season produced a greater response in the growth of the trees than either watering or adequate fertilization. It appeared that there was some important factor other than lack of moisture or nutrients that was retarding the growth of the uncultivated trees.

In order to get more information on this point an experiment was set up to determine whether the beneficial effects of cultivation were due primarily to keeping the soil free of weeds or to stirring of the soil.

### EXPERIMENTAL PROCEDURE

Two locations were chosen, one near Ocala, Florida, on Norfolk fine sand adjacent to the previous year's experiment (1) and one near Hague, Florida, on Gainesville fine sandy loam.

At Ocala on February 20, 1946, seedling and budded nursery trees were planted about 5 feet apart in three rows 30 feet part. The seedling trees were 1 year old and the budded trees had 1-year-old tops and 2-year-old roots. All trees were cut back to 6 or 8 inches and one bud was allowed to develop. Each plot consisted of two seedling and two budded trees of variety F-99, and a 10-foot space was left between plots in the row. The planting consisted of 27 plots to which nine treatments were assigned, as given below, thus making three replications in randomized block design.

*Treatment 1:*—Spading (soil turned to a depth of 6 to 8 inches) every 2 weeks up to and including October 15.

*Treatment 2:*—Hoeing (soil turned to a depth of 3 to 4 inches) every 2 weeks up to and including October 15.

*Treatment 3:*—Flat hoeing (weeds cut at ground surface without disturbing the soil) every 2 weeks up to and including October 15.

*Treatment 4:*—Spading every 2 weeks up to and including June 15 (soil turned to a depth of 6 to 8 inches).

*Treatment 5:*—Hoeing every 2 weeks up to and including June 15 (soil turned to a depth of 3 to 4 inches).

*Treatment 6:*—Flat hoeing every 2 weeks up to and including June 15 (weeds cut at ground surface without disturbing the soil).

*Treatment 7:*—Infrequent hoeing; April 15, May 27, August 5, and September 4 (soil turned to a depth of 3 to 4 inches).

*Treatment 8:*—Mulch-mixture of about half pine straw and half Alyce clover hay 10 to 12 inches deep weighing about 15 pounds placed within a 2-foot radius of the tree. An additional 4-inch application of pine straw (about 5 pounds) was made in the middle of the season.

*Treatment 9:*—Spading every 4 weeks up to and including June 15 (soil turned at a depth of 6 to 8 inches).

All treatments except mulch were used on an area within a 3-foot radius of the tree and were started on April 4, 1946 after growth had begun. On April 18 a soil application was made of  $\frac{1}{2}$  pound per tree of 6-6-6 fertilizer containing the equivalent of 4 per cent of  $MgO$ , 1.50 per cent of  $ZnO$ , 0.50 per cent of  $MnO$ , 0.50 per cent of  $CuO$ , and 0.50 per cent of  $FeO$ , all present as sulfates, and 0.20 per cent of  $B_2O_3$  as borax. Another application of  $\frac{1}{4}$  pound per tree was made on June 11.

At the Hague location there were enough seedling and budded trees of variety F-99 for only 21 plots to which were assigned treatments 1 to 7, inclusive, making three replications in a randomized block design. The trees in these plots were planted at the same time and were handled approximately the same as those in the Ocala location except that no June application of fertilizer was made.

## RESULTS AND DISCUSSION

The length of trunk, its circumference at 4 inches above the base, and the length of the primary branches were measured on November 1. The trees at Hague had made a greater, but considerably more variable growth than those at Ocala. At both locations the budded trees exceeded the seedlings in length of trunk and in weighted top growth (length of trunk plus one-half the total length of the side branches), but not in cross-sectional area of the trunk. Analysis of the data showed that in no case was there any statistically significant interaction between type of tree and treatment; that is, the treatments had relatively the same effects on seedlings and budded trees. Therefore data on growth, presented in Table I, are averages for seedlings and budded trees.

It is readily apparent that at both locations the infrequent hoeing resulted in much poorer growth than any other treatment. At Ocala spading every 4 weeks until June 15 produced better growth than infrequent hoeing, the differences in top growth being statistically significant at or near the .01 level and the difference in cross-sectional area of the trunks being statistically significant at the .05 level. Mulching or cultivating frequently, either throughout the season or until June 15, produced better growth than spading every 4 weeks, by margins that in almost every instance attain statistical significance at the .01 level. Differences in growth between the trees infrequently hoed and those mulched or those hoed frequently, in every instance exceeded the values required for statistical significance at the .001 level. At Hague the differences were as great as at Ocala, but owing to the greater variability in growth of the trees and higher error terms, statistical significance of the differences was not so high.

The results of this experiment indicate that the beneficial effect of cultivation on tree growth was due primarily to keeping the area around the trees free of weeds. Whether or not the soil was stirred was unimportant, as is shown by the fact that the flat hoeing in which

TABLE I—EFFECT OF FREQUENCY AND METHOD OF CULTIVATION ON ONE SEASON'S GROWTH OF ONE-YEAR-OLD TUNG TREES TRANSPLANTED IN FEBRUARY 1946

Treatments	Measurements at End of Growing Season*					
	Ocala, Florida			Hague, Florida		
	Length of Trunk (Inches)	Weighted Top Growth** (Inches)	Cross-Section of Trunk (Sq Ins)	Length of Trunk (Inches)	Weighted Top Growth** (Inches)	Cross-Section of Trunk (Sq Ins)
Spading every 2 weeks up to and including Oct 15.....	67	117	0.74	98	225	1.81
Hoeing every 2 weeks up to and including Oct 15.....	72	145	0.93	88	184	1.30
Flat hoeing every 2 weeks up to and including Oct 15.....	71	148	0.98	81	172	1.21
Spading every 2 weeks up to and including Jun 15.....	72	139	0.90	79	153	0.99
Hoeing every 2 weeks up to and including Jun 15.....	66	121	0.71	86	182	1.36
Flat hoeing every 2 weeks up to and including Jun 15.....	72	128	0.82	72	132	0.88
Infrequent hoeing.....	25	27	0.17	50	47	0.32
Mulch.....	74	139	1.01	—	—	—
Spading every 4 weeks up to and including Jun 15.....	48	66	0.43	—	—	—
Least significant difference at 0.05.....	14	29	0.25	18	92	0.88
0.01.....	20	40	0.34	25	129	1.24
0.001.....	27	54	0.46	35	182	1.77

\*Average of 12 trees (three replications and four trees in each plot).

\*\*Weighted top growth is the length of the trunk plus  $\frac{1}{2}$  the total length of the side branches, if any.

the soil was relatively undisturbed gave almost as good results as hoeing or spading in which the soil was stirred. The mulch treatment was equally effective, and in this treatment also the soil around the tree was not disturbed but the area around the tree was free of weeds.

On the average the growth of trees that were cultivated throughout the season exceeded that of those for which the cultivation was terminated on June 15, when less than half the total growth of the season had been made. However, the differences do not attain statistical significance and are too small to be of any practical importance. This was true even though there was considerable weed growth by the end of the season around the trees not cultivated after June 15.

Although it has long been known that it is important to keep the cultivated area free of weeds for successful crop production, the reasons for it have not always been clearly defined. It has been generally agreed that with tree crops as with other crops the main benefits from controlling weeds are the conservation of moisture and nutrients, particularly nitrogen. The present experiment taken together with the results of the 1945 study (1) makes it questionable that moisture and nutrients were factors of prime importance in limiting growth. The infrequently cultivated tung trees that were watered frequently last year failed to grow as well as the unwatered but frequently cultivated trees. During 1946 there was ample rainfall, yet the infrequently hoed trees failed to respond.

As for nutrients, in both 1945 and 1946 the trees were adequately

fertilized and there was no visible evidence of a lack of any particular element. In both years leaf samples were collected from the experimental plots. The data obtained this year at Hague, which are given in Table II, further suggest that lack of nutrients probably was not the limiting factor in the growth of the uncultivated trees. The data

TABLE II—LEAF ANALYSES ON SAMPLES COLLECTED AUGUST 22, 1946  
FROM THE CULTIVATION PLOTS AT HAGUE, FLORIDA

Treatments	Percentage of Constituents on Dry Weight Basis*				
	N	P	K	Ca	Mg
Spading every 2 weeks up to and including Oct 15	2.33	0.17	0.54	2.28	0.48
Hoeing every 2 weeks up to and including Oct 15	2.39	0.18	0.56	2.13	0.48
Flat hoeing every 2 weeks up to and including Oct 15.....	2.54	0.19	0.60	2.10	0.42
Spading every 2 weeks up to and including Jun 15	2.06	0.16	0.64	1.90	0.40
Hoeing every 2 weeks up to and including Jun 15	2.16	0.18	0.54	2.14	0.48
Flat hoeing every 2 weeks up to and including Jun 15.....	2.10	0.17	0.60	2.02	0.47
Infrequent hoeing.....	2.23	0.18	0.59	1.88	0.44

\*Average of three replications.

show that the difference in composition of the leaves in August would not account for the difference between the trees that made very poor growth in the infrequently hoed plots and those that made excellent growth on the frequently cultivated plots. The samples for leaf analysis were taken August 22 and the possibility of a deficiency in nutrients early in the growing season, before the tung roots were well established, is not excluded. Similar data were obtained at Ocala in 1945.

Further work on this problem is planned for 1947.

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# The Relation of Fertilization with Copper and Nitrogen to Copper Deficiency Symptoms, Leaf Composition, and Growth of Tung

By JOSEPH HAMILTON and SEYMOUR G. GILBERT, U. S.  
*Department of Agriculture, Gainesville, Fla.*

MOST reports on copper deficiency (1, 2, 3, 5) have described the deficiency symptoms and their alleviation by the application of copper salts with little regard to the effect of elements other than copper. The existence of a physiological balance between copper and nitrogen in citrus was suggested, however, by Camp and Fudge (3), and a biochemical interaction between copper and nitrogen was demonstrated in copper deficiency of tung (*Aleurites fordii* Hemsl.) (7). Experiments demonstrating the effect of elements other than copper, particularly nitrogen, on the development of copper-deficiency symptoms in tung have been described in a preliminary report (6). A more complete report on this work is presented here.

## EXPERIMENT I

The relation between copper and the primary fertilizer elements in tung was first studied in 1943 in a mineral nutrition experiment at Vlague, Florida. In this factorial experiment (8) there were two replications of 27 treatments including all possible combinations of three levels each of nitrogen, phosphorus, and potassium. Each plot consisted of six budded trees, two each of the selections L-14, F-193, and A-12, planted in March 1943. The fertilizers and a blanket treatment of 1 ounce of copper sulfate per tree were applied to the soil May 21 and 22. Notwithstanding the application of copper to the soil, copper-deficiency symptoms began to appear in June, and their severity and extent were estimated on July 7, on a scale ranging from 0 for a normal shoot to 5 for one very severely affected. Every primary shoot on a tree was scored and the mean score per shoot was calculated. Thus the score is determined by both the number of shoots affected and the severity of damage to the individual shoots. The principal factor affected in these experiments was the severity of the damage to the individual shoots since copper deficiency represses shoot growth. On July 14 and 17, the length of the shoots was measured.

Within 6 weeks after the application of copper sulfate and the fertilizers, the trees that received the low level of nitrogen showed only slight copper-deficiency symptoms (Table I). The trees that received the medium and high levels of nitrogen were more seriously affected and thus had a higher score. Potassium reduced the copper-deficiency score by an amount statistically significant but relatively unimportant in comparison with the increase from nitrogen. There was no indication that phosphorus affected the incidence of copper-deficiency symptoms. No interaction of the fertilizer elements attained statistical significance. The clone F-193 was more severely affected than L-14



and A-12, which indicates a difference in varietal susceptibility, under the conditions of this experiment.

On July 7, a copper sulfate solution (1-50) was applied as a spray to all trees. All copper-deficient trees recovered temporarily, as shown by the new growth; but by September the new growth of some 15 per cent of the trees again showed copper-deficiency symptoms. The

TABLE I—THE EFFECT OF FERTILIZER TREATMENT ON INCIDENCE OF COPPER-DEFICIENCY SYMPTOMS AND SHOOT GROWTH OF TUNG TREES. (HAGUE, FLORIDA, JULY, 1943.) TREES SCORED 0 TO 5 ACCORDING TO SEVERITY OF SYMPTOMS

Fertilizer Equivalent	Amount Per Tree (Pounds)	Variety					
		L-14		F193		A12	
		Score*	Shoot Length† (Cms)	Score*	Shoot Length† (Cms)	Score*	Shoot Length† (Cms)
N	0.01	0.25	91	0.72	290	0.32	278
N	0.03	0.85	94	1.46	310	1.09	310
N	0.09	1.79	98	2.01	343	1.66	306
P <sub>2</sub> O <sub>5</sub>	0.01	1.04	94	1.29	295	0.91	287
P <sub>2</sub> O <sub>5</sub>	0.03	0.80	99	1.40	311	1.01	306
P <sub>2</sub> O <sub>5</sub>	0.09	1.04	91	1.50	337	1.04	302
K <sub>2</sub> O	0.015	1.07	94	1.61	324	1.31	268
K <sub>2</sub> O	0.045	0.94	91	1.26	304	0.99	343
K <sub>2</sub> O	0.135	0.88	98	1.31	314	0.67	283

\*The score of an individual tree is the sum of the scores of the shoots divided by the total number of shoots on the tree. Each reading in the table is the mean of the individual scores of 36 trees.

†The total new shoot growth of each tree was measured. Each reading in the table is the mean shoot length of 36 trees.

average copper-deficiency scores determined on September 11 on the previous basis for the three varieties were .14, .39, and 1.06, respectively, for the low, intermediate and high levels of nitrogen. These effects of the fertilizer treatments are highly significant. It is thus evident that soil applications of nitrogen increase the incidence of copper-deficiency symptoms shown by the trees.

## EXPERIMENT II

To obtain further evidence on the interaction of copper and nitrogen, an experiment was set up in the spring of 1944 at two locations about 1 mile apart in the same copper-deficient area where the previous work had been done. At location I the soil was Gainesville fine sandy loam. At location II the soil was Arredonda loamy fine sand with localized wet spots during the rainy season. At each location there were two replications of 16 treatments comprising all factorial combinations of four levels each of copper and nitrogen. Each plot consisted of two transplanted 1-year-old seedling trees. The first three levels of copper sulfate, applied on May 25, were 0,  $\frac{1}{8}$ , and 1 ounce per tree. In order to avoid serious toxic effects, the fourth or highest level of copper sulfate consisted of 1 ounce applied May 25, and 1 ounce applied July 1. The four levels of nitrogen, namely, .01, .03, .09, and .18 pound of elemental nitrogen per tree, half as sodium nitrate and half as ammonium sulfate, were applied May 25. Both copper and

nitrogen were applied as dry salts on the soil on a circular area having a radius of 1 foot from the trunk of the tree.

On July 17 evidence of toxicity was observed on a few of the trees that had received 1 ounce of copper sulfate, and by July 23 about 10 per cent of these trees had shed a few basal leaves. On that date none showed definite symptoms of copper deficiency. By July 29, however, toxicity symptoms had disappeared and copper-deficiency symptoms were prevalent, the trees that received the low levels of copper being much more severely affected than those that received the high levels. The injurious effects of nitrogen on copper-deficiency symptoms were less outstanding than the beneficial effects of copper, but in general the trees that received the high levels of nitrogen were more severely affected than those that received the low levels. Scores for vigor of tree growth indicated that copper had produced no effect, but that the higher the rate of nitrogen applied, the lower the vigor of the tree.

On September 5, all trees in experiment II were again scored for copper-deficiency symptoms. The trees that received the lowest level of nitrogen, regardless of the level of copper applied, and the trees that received the highest level of copper, regardless of the level of nitrogen, were only slightly affected by copper deficiency (Table II). The disorder was most serious on trees that received high levels of nitrogen combined with the low levels of copper. The analysis of variance indicates that despite the two different soil types, the difference between locations was unimportant. The effects of copper and of nitrogen were highly significant, and the low value for the interaction indicated that each tended to have the same effect at all levels of the other.

TABLE II.—THE EFFECT OF COPPER AND NITROGEN APPLICATIONS ON THE SCORES FOR COPPER-DEFICIENCY SYMPTOMS OF TUNG TREES DURING THE FIRST YEAR IN THE ORCHARD. (TWO LOCATIONS NEAR HAGUE, FLORIDA, SEPTEMBER 5, 1944). TREES SCORED FROM 0 TO 5 ACCORDING TO SEVERITY OF SYMPTOMS\*

Copper Sulfate Applied Per Tree (Ounces)	Nitrogen Applied (Pounds Per Tree)				
	0.01 (Score)	0.03 (Score)	0.09 (Score)	0.18 (Score)	Mean (Score)
0.....	0.25	1.50	1.75	3.12	1.66
$\frac{1}{2}$ .....	0.12	0.25	1.12	2.50	1.00
1.....	0.25	0.25	1.12	2.12	0.94
2.....	0.00	0.12	0.38	0.25	0.19
Mean.....	0.16	0.53	1.09	2.00	0.95

\*Each reading is the mean of the scores of eight trees.

On September 11, 1944, separate samples of midshoot and of terminal leaves were taken from each plot and were subsequently analyzed for nitrogen. The average nitrogen content of the terminal leaves, 2.11 per cent, was lower than that of the midshoot leaves, 2.31 per cent; but the low value of F for the interaction of treatment with position (Table III) showed that the response to treatment was the same in both positions. Therefore, the data are presented as averages for terminal and midshoot leaves. At location I, which was well

drained, the leaves were deep green in color and had an average nitrogen content of 2.60 per cent; at location II, which was poorly drained, the leaf color suggested a moderate nitrogen deficiency and the average nitrogen content was 1.81 per cent. At both locations the nitrogen content of the leaves was in direct relation to level of nitrogen applied and in inverse relation to the level of copper; the effects of both elements attained high statistical significance (Table III). The

TABLE III—PERCENTAGE NITROGEN IN LEAVES\* OF TUNG TREES, DRY BASIS, AS AFFECTED BY LEVELS OF COPPER AND NITROGEN APPLIED. (HAGUE, FLORIDA, SEPTEMBER 11, 1944)

Copper Sulfate Per Tree (Ounces)	Nitrogen Applied (Pounds Per Tree)										
	0.01		0.03		0.09		0.18		Means		
	Locations (Per Cent)		Locations (Per Cent)		Locations (Per Cent)		Locations (Per Cent)		Locations (Per Cent)		Locations (Per Cent)
	I	II	I	II	I	II	I	II	I	II	I and II
0	2.27	1.55	2.46	1.85	3.11	1.87	3.67	2.92	2.88	2.05	2.46
1/4	2.14	1.69	2.48	1.65	2.61	1.72	3.10	2.25	2.58	1.83	2.20
1	1.98	1.55	2.37	1.71	2.61	1.61	2.95	1.80	2.48	1.67	2.07
2	2.18	1.39	2.20	1.75	2.74	1.76	2.71	1.93	2.46	1.70	2.08
Means....	2.14	1.54	2.38	1.74	2.77	1.74	3.11	2.22	2.60	1.81	2.21
	1.84		2.06		2.25		2.67				

\*Average of Midshot and terminal sample.

effect of the level of copper on nitrogen content of the leaves was greatest at the high rates of nitrogen application, the difference attaining statistical significance approximately at the .05 level. The interaction of treatment with location was statistically significant, thus indicating that the same results would not necessarily be expected at other locations. However, the effects of the nitrogen and of the copper were highly significant when tested by using the interaction of treatment with location as an error term; hence the same general trends would be expected at any location within the copper deficient area, represented by the two locations used.

Measurements taken January 20, 1945, showed that the cross-sectional areas of the trunks were in inverse relation to the level of nitrogen applied, the difference attaining statistical significance close to the .05 level (Table IV). A decrease in total size of tops was correlated with the decrease in trunk area, but fell far short of statistical significance at the .05 level. The different levels of copper applied had no consistent effect on growth. Similar effects of level of nitrogen supply on growth of newly planted tung trees were observed in another test, which adjoins experiment II at one location.

## DISCUSSION

The experiments conducted both in 1943 and in 1944 support the hypothesis previously advanced (6, 7) that for normal growth a satisfactory physiological balance between copper and nitrogen must be maintained within the leaves of the trees. If this balance is disturbed during a period of active growth by either insufficient copper or ex-

TABLE IV—THE EFFECT OF COPPER AND NITROGEN APPLICATIONS ON THE CROSS-SECTIONAL AREA OF TRUNK\* AND ON CALCULATED SIZE† OF TUNG TREES. (HAGUE, FLORIDA, JANUARY 20, 1945)

Copper Sulfate Applied Per Tree (Ounces)	Nitrogen Applied (Pounds Per Tree)									
	0.01		0.03		0.09		0.18		Mean	
	Cross-Sectional Area (Sq Cms)	Size (Cms)	Cross-Sectional Area (Sq Cms)	Size (Cms)	Cross-Sectional Area (Sq Cms)	Size (Cms)	Cross-Sectional Area (Sq Cms)	Size (Cms)	Cross-Sectional Area (Sq Cms)	Size (Cms)
0	6.6	330	5.2	302	3.9	194	2.7	205	4.6	258
1/4	5.2	312	6.6	350	6.2	338	5.2	297	5.8	324
1	7.3	345	5.3	316	4.7	310	3.1	200	5.1	293
2	5.6	263	6.5	296	4.6	253	5.1	303	5.4	279
Mean	6.2	312	5.9	316	4.8	274	4.0	251	5.2	288

\*Trees were cut back to 8 inches at planting and subsequently were suckered to one shoot. Trunk cross-sectional area was taken 15 centimeters above point of origin of the new shoot.

†The calculated size was equivalent to the length of trunk plus one-half the length of primary branches plus one-fourth the length of secondary shoots.

cessive nitrogen, copper-deficiency symptoms develop. Copper deficiency did not significantly affect tree growth in either of the experiments reported herein, as determined from the cross-sectional area of trunk or size of tree. However, the trees in these experiments did not exhibit severe copper deficiency and the stunted growth or die-back which are usually associated with it.

In these experiments no treatment among the wide range in levels of nitrogen and of copper fertilization had beneficial effect on the growth of tung trees during the first year. This indicates that factors other than lack of nitrogen and copper limited tree growth on the soils on which these experiments were conducted. In view of the lack of beneficial effects from the nitrogen applications and the difficulty of maintaining sufficient available copper in the soil over an extended period, it appears that for soil applications low rates of nitrogen fertilization and moderate rates of applications of copper should be employed. If suitable equipment is available, operators of tung plantings on copper-deficient soils should consider spray applications, which give a uniform and complete, though temporary, control of copper deficiency.

### SUMMARY

A study was made of the effect of applications of copper and other fertilizer elements on copper-deficiency symptoms, nitrogen content of leaves, and growth of tung trees.

In experiment I the effect was determined of three levels each of nitrogen, phosphorus, and potash and a uniform application of copper, on copper-deficiency symptoms and growth of young tung trees. Although copper-deficiency symptoms occurred on trees receiving the low rate of nitrogen application, such symptoms became progressively more serious at the medium and high rates of nitrogen application. The application of potassium decreased the incidence of copper-deficiency symptoms by a small but statistically significant amount.

Phosphorus had no effect. None of the fertilizers applied had an effect on shoot growth.

In experiment II, in which four levels each of copper and nitrogen were applied, very little copper deficiency occurred on trees at low rates of nitrogen application, regardless of the level of copper applied, or on trees at high levels of copper supply, regardless of the level of nitrogen applied. The combination of high levels of nitrogen with low levels of copper resulted in severe copper deficiency. The nitrogen content of the leaves was in direct relation to the rate of application of nitrogen; but it was reduced by increases in the rate of copper applied. The nitrogen applied tended to decrease the cross-sectional area of the tree trunks but had no effect on the size of the tops. Copper had no consistent effect on tree growth.

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## The Effect of Different Rates of Application of Nitrogen on Biennial Bearing in Tung

By GEORGE F. POTTER, BENJAMIN G. SITTON and LEWIS P. McCANN, *U. S. Department of Agriculture, Bogalusa, La.*

IN connection with studies of fruit bud formation in tung trees, conducted at the U. S. Field Laboratory for Tung Investigations, Bogalusa, Louisiana, by McCann *et al* (1), an experiment was begun in 1941 to determine the effects of fruit bearing and of level of nitrogen supply on fruit bud differentiation. On April 5, 1941, during the flowering period, 24 6-year-old seedling tung trees were selected from an area including about 3 acres within a large commercial orchard of seedling trees in St. Tammany Parish, Louisiana. The trees were selected for uniformity in flowering habit, current crops, previous crops, mode of fruit production, and branching habit. They were divided into four replications or blocks of six trees each. Within each replication three nitrogen levels were maintained over the period 1941 to 1944 inclusive, each represented by two trees, of which one was allowed to retain its crop in 1941 and the other had the entire 1941 crop removed soon after the fruit had set. The trees at the high level of nitrogen supply were to receive 9 pounds of nitrate of soda per tree annually in three applications of 3 pounds each, at intervals of 1 month, commencing at the blossom period. Those at the intermediate level of nitrogen were to receive 3 pounds of nitrate of soda per tree, in three applications of 1 pound each at the same intervals. The trees at the low level of nitrogen supply were to receive only that nitrogen available from the soil and from cover crops. However, in 1941, the first year of the experiment, the grower-cooperator inadvertently applied nitrogen equivalent to 3.9 pounds of nitrate of soda per tree to all trees, which was of necessity accepted as the intermediate level for that season. Supplementary applications were made to the trees at the high level of nitrogen supply as required to bring the total up to that originally planned. In an attempt to decrease the nitrates available to the trees designated to receive the low level, rice straw was incorporated in the soil. It is a recognized principle that organisms effecting decomposition of unhumified organic matter having a high carbon-nitrogen ratio compete with the crop for the nitrogen supply of the soil (2). Fortunately the nitrogen applied by the owner of the orchard was placed in furrows running along the rows at the outer extremities of the branches and hence could have had but little effect in hastening decomposition of the rice straw which was incorporated in the surface foot of the soil at the rate of 4 tons per acre, beginning 3 feet from the trunk and extending out to the periphery of the branches. It is believed that throughout most of the season this straw treatment substantially lowered the level of nitrogen available to these trees. In the succeeding seasons, 1942 to 1944 inclusive, the levels of nitrogen were maintained as originally planned.

Samples of leaves were collected annually in August 1942, 1943, and 1944, for determination of the nitrogen content. One sample was

taken from each tree, consisting of a midshoot leaf removed without its petiole from each of the 48 modal-length shoots from representative positions on four sides of the tree. The 24 samples were dried in an oven at 70 degrees C and nitrogen was determined by the Kjeldahl-Gunning method<sup>1</sup>.

Over the three-year period the percentages of nitrogen in the leaves of trees receiving the high, intermediate, and low levels of nitrogen were, respectively, 2.42, 2.24, and 1.92. In each season the value of F for effect of level of nitrogen supplied on percentage of nitrogen in the leaves is greater than is required for statistical significance at the .001 level (Table I). These data give conclusive evidence

TABLE I—EFFECT OF CROP AND RATE OF APPLICATION OF NITROGEN UPON THE PERCENTAGE OF NITROGEN IN TUNG LEAF SAMPLES IN AUGUST (DRY WEIGHT BASIS)

Year	Defruited in 1941 (Per Cent)				Bearing in 1941 (Per Cent)				F Found	
	Rate of Application of Nitrogen				Rate of Application of Nitrogen				Rate of Application of Nitrogen	Crop Borne in 1941
	Low	Medium	High	Average	Low	Medium	High	Average		
1942	1.92	2.37	2.70	2.33	1.54	2.19	2.42	2.05	72.00	23.00
1943	1.90	2.20	2.34	2.14	2.03	2.50	2.48	2.33	15.88	7.34
1944	2.09	2.02	2.36	2.16	1.99	2.14	2.24	2.12	13.91	*
F required for significance at .05									3.68	4.54
.01									6.36	6.68
.001									11.34	16.59

\*Mean square for treatment lower than mean square for error.

that three planes of nitrogen assimilation were maintained in the trees throughout the period of the experiment. In 1942 the percentage of nitrogen was greater in the leaves from the trees defruited in 1941 than in the leaves from the trees bearing in 1941. In 1943 the percentages of nitrogen in the two sets were in the reverse rank, but in 1944 there was no significant difference.

On each of four dates at 2-week intervals, beginning July 9 and ending August 20, 1941, a representative random sample of 16 mixed terminal buds, in which the blossoms are initiated, was collected from each of the 24 trees. These buds were examined microscopically and the stage of development of the embryonic flowers was determined. It was found that the stage of development varied widely from individual tree to individual tree but that neither the defruiting nor the level of nitrogen supply had produced any significant effect upon the rate of flower bud development.

However, in the spring of 1942 and in each of the two succeeding seasons, the number of pistillate flower buds on 40 terminal shoots of the previous season, 10 taken at random on each of four sides of the tree, were counted. These data, presented in Table II, on the basis of average number of pistillate flowers per terminal bud, show that

<sup>1</sup>The writers are indebted to Harold M. Sell, formerly associate chemist, U. S. Field Laboratory for Tung Investigations, Gainesville, Florida, for these analyses.

TABLE II—EFFECT OF CROP AND RATE OF APPLICATION OF NITROGEN UPON THE NUMBER OF PISTILLATE TUNG FLOWERS PER TERMINAL SHOOT OF THE PREVIOUS SEASON

Year	Defruited in 1941 (Per Cent)				Bearing in 1941 (Per Cent)				F Found	
	Rate of Application of Nitrogen				Rate of Application of Nitrogen				Rate of Application of Nitrogen	Crop Borne in 1941
	Low	Medium	High	Average	Low	Medium	High	Average		
1942	1.12	1.80	2.46	1.79	0.35	0.48	0.52	0.45	3.45	32.64
1943	0.18	0.17	0.14	0.16	0.36	1.22	0.65	0.74	2.34	12.39
1944	1.83	2.89	2.56	2.43	1.80	2.00	2.31	2.01	1.18	1.05
F required for significance at .05									3.68	4.54
.01									6.36	6.68
.001									11.34	18.59

trees completely defruited in 1941 tended to have abundant flower formation in 1942 and 1944. The trees that bore heavily in 1941, on the other hand, tended to produce the most flowers in 1943 and to have a lower number of flowers per terminal shoot in 1942 and 1944 than did trees defruited in 1941. The results were very clear-cut in 1942 but were obscured somewhat in succeeding years by a rather severe late winter freeze that occurred in March 1943 and greatly reduced the number of flower buds that opened that season. On the basis of these random counts the trees defruited in 1941 produced 2.43 pistillate flowers per terminal shoot in 1944, their "on" year, whereas those that fruited in 1941 and, therefore, were in the "off" year in 1944, produced 2.01 pistillate flowers per terminal bud. In view of the variation between individual trees, this difference is too small to attain any statistical significance but, as will be shown later, it is supported by more precise data on yield, which show that the tendency to biennial bearing set up by defruiting in 1941 persisted through the freeze of 1943 and into the season of 1944.

The data on the total weight of fruit produced (Table III) show very clearly that the trees that bore heavily in 1941 had relatively light crops in 1942 and even in 1944. The trend due to defruiting persisted through four years, one of which was a serious frost year,

TABLE III—EFFECT OF CROP AND RATE OF APPLICATION OF NITROGEN  
UPON YIELD OF AIR-DRY TUNG FRUIT PER TREE

Year	Defruited in 1941 (Per Cent)				Bearing in 1941 (Per Cent)				F Round	
	Rate of Application of Nitrogen				Rate of Application of Nitrogen				Rate of Application of Nitrogen	Crop Borne in 1941
	Low	Medium	High	Average	Low	Medium	High	Average		
1941	0	0	0	0	40.2	42.0	40.9	41.0	—	—
1942	59.0	58.0	89.5	68.9	11.2	19.5	20.4	18.2	6.03	87.02
1943	6.5	1.7	4.0	4.1	8.7	32.0	17.0	19.2	4.71	36.28
1944	59.4	83.2	99.5	80.7	53.5	58.7	72.6	61.0	5.74	7.19
Average	31.2	35.7	48.2	38.4	28.4	38.0	37.7	34.8	7.65	1.36
F required for significance at .05									3.68	4.54
.01									6.36	6.68
.001									11.34	16.59



with differences that in each season attained high statistical significance. The trees defruited in 1941 produced an enormous crop in 1942, an average of 68.9 pounds of air-dry fruit per tree, actually more than was produced in the two seasons by the trees that bore heavily in 1941. At first thought such a result seems impossible, but it may be understood by taking the age of the trees into consideration. The nonbearing 6-year-old trees increased markedly in size during the season of 1941 and then bore the maximum crop per unit of bearing surface in 1942. The trees that bore in 1941 grew but little that season and in 1942 produced only a small off-year crop on trees that still had comparatively little bearing surface.

The excessive crop borne by the defruited trees in 1942, together with the freeze, reduced their 1943 crop to practically nothing. The trees "came back" in 1944, with a record production of 80.7 pounds of air-dry fruit per tree. The blossoms (Table II) and the yields (Table III) produced in 1943 by both sets of trees must be interpreted as the results of two factors, (a) the number of flowers differentiated, and (b) the relative cold resistance of the flowering buds. Both factors are influenced by size of crop borne in 1942.

The total yield for the four years appears to have been increased slightly by defruiting in 1941, but the increase is too small to attain statistical significance. Average yields, expressed as pounds of air-dry fruit per tree per year, were 57.3, 49.2, and 39.8 for the high, intermediate, and low levels of nitrogen, respectively. In 1943 yields tended to be erratic, probably due to inherent differences in cold resistance of the individual trees. In 1942 and 1944, the nitrogen increased yields whether the trees were in the "on" or the "off" years, but to a greater extent for trees in the "on" year. The coefficients of variability, 80.0, 79.8, and 89.4 per cent, respectively, for the low, intermediate, and high levels of nitrogen, indicate no tendency for nitrogen to reduce biennial bearing.

A sample of 100 fruits was taken from each tree each season for oil analysis. Extensive and precise experiments conducted by Sitton and Loustalot (3) have shown conclusively that a high level of nitrogen fertilizer tends to reduce the percentage of oil in the tung kernel, but to increase the percentage of kernel in the whole fruit to such an extent that there is a substantial net gain in the percentage oil in the whole fruit. However, the degree of precision attained in this rather small-scale experiment was not sufficient to show all the characteristic effects of the different nitrogen levels on fruit composition. The expected trend in oil in the kernel was observed in fruit from the bearing trees in 1941, in fruit from all trees in 1942, and to a lesser extent in 1944 (Table IV), but not in 1943<sup>2</sup>. No consistent effect of level of nitrogen upon the percentage of kernel in the whole fruit (Table V) or of oil in the whole fruit (Table VI) was observed.

The defruiting in 1941 very significantly affected the composition of the crop of 1942, the percentage of oil in the kernel being increased from 67.0 to 68.4, that of kernel in the whole fruit from 32.3 to 34.7,

<sup>2</sup>The writers are indebted to Frank C. Pack, A. F. Freeman, and A. J. Loustalot, for the oil determinations.

TABLE IV—EFFECT OF CROP AND RATE OF APPLICATION OF NITROGEN UPON THE PERCENTAGE OF OIL IN TUNG KERNELS\*

Year	Defruited in 1941 (Per Cent)				Bearing in 1941 (Per Cent)				F Found	
	Rate of Application of Nitrogen				Rate of Application of Nitrogen				Rate of Application of Nitrogen	Crop Borne in 1941
	Low	Medium	High	Average	Low	Medium	High	Average		
1941	—	—	—	—	65.7	63.5	61.9	63.7	—	—
1942	70.2	68.0	67.0	68.4	68.9	67.2	64.7	67.0	18.90	8.83
1943	67.4	66.4	68.2	67.3	66.3	66.6	68.7	67.1	4.88	†
1944	64.7	60.6	62.4	62.5	64.4	61.9	61.0	62.4	7.64	1.06
F required for significance at .05									3.68	4.54
.01									6.36	6.68
.001									11.34	16.59

\*From fruits in equilibrium with the vapor pressure of a saturated solution of calcium chloride at room temperature.

†Mean square for treatment lower than mean square for error.

TABLE V—EFFECT OF CROP AND RATE OF APPLICATION OF NITROGEN UPON THE PERCENTAGE OF KERNEL IN THE WHOLE FRUIT\*

Year	Defruited in 1941 (Per Cent)				Bearing in 1941 (Per Cent)				F Found	
	Rate of Application of Nitrogen				Rate of Application of Nitrogen				Rate of Application of Nitrogen	Crop Borne in 1941
	Low	Medium	High	Average	Low	Medium	High	Average		
1941	—	—	—	—	37.1	35.8	37.3	36.7	—	—
1942	33.3	34.0	36.7	34.7	30.4	33.2	32.6	32.1	3.23	8.30
1943	33.4	34.1	33.5	33.7	33.5	35.1	32.5	33.7	†	†
1944	32.1	33.1	32.9	32.7	32.3	32.0	31.3	31.9	8.68	†
F required for significance at .05									3.68	4.54
.01									6.36	6.68
.001									11.34	16.59

\*Fruits in equilibrium with the vapor pressure of a saturated solution of calcium chloride at room temperature.

†Mean square for treatment lower than mean square for error.

TABLE VI—EFFECT OF CROP AND RATE OF APPLICATION OF NITROGEN UPON THE PERCENTAGE OF OIL IN THE WHOLE FRUIT\*

Year	Defruited in 1941 (Per Cent)				Bearing in 1941 (Per Cent)				F Found	
	Rate of Application of Nitrogen				Rate of Application of Nitrogen				Rate of Application of Nitrogen	Crop Borne in 1941
	Low	Medium	High	Average	Low	Medium	High	Average		
1941	—	—	—	—	24.7	22.6	23.1	26.8	—	—
1942	23.4	23.2	24.6	23.7	20.9	22.3	21.1	21.4	†	10.15
1943	22.8	22.6	22.6	22.7	23.2	23.4	21.2	22.6	†	†
1944	20.7	20.1	20.5	20.4	20.8	19.8	19.1	19.9	†	†
F required for significance at .05									3.68	4.54
.01									6.36	6.68
.001									11.34	16.59

\*Fruits in equilibrium with the vapor pressure of a saturated solution of calcium chloride at room temperature.

†Mean square for treatment lower than mean square for error.

and that of oil in the whole fruit from 21.4 to 23.7, as compared to fruit from corresponding trees that bore a full crop in 1941. The conclusion seems warranted that in a season when no crop is produced the tung tree is able to store up reserves, in consequence of which the oil content of the succeeding crop is considerably increased.

#### SUMMARY

Complete defruiting of heavily loaded tung trees in 1941 set up a biennial bearing tendency that persisted through 1944, even though the crop on both defruited and check trees was largely destroyed by frost in 1943. Applications of nitrogen increased average yields, but did not reduce the alternate bearing tendency. The defruiting significantly increased percentage oil content of the succeeding crop.

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## Quick Tests for Potassium and Magnesium in Tung Leaves and Difference in Composition of Different Parts of the Petiole

By MATTHEW DROSDOFF and D. CHARLES NEARPASS,  
*U. S. Department of Agriculture, Gainesville, Fla.*

DEFICIENCIES both of potassium and of magnesium are widespread in tung orchards of the southeastern United States. In many instances the leaf symptoms of these two deficiencies are so similar as to render it difficult to distinguish between them, and either or both of them may occur in one orchard. In case of doubt as to the identity of the leaf symptoms it has been the usual practice in this laboratory to diagnose the trouble by means of a quantitative analysis of the leaves. Because of the need for a less expensive and more rapid method of differentiating between potassium and magnesium deficiencies in tung trees, it was decided to attempt to adapt one of the quick test techniques to this purpose.

After preliminary trials with several procedures, it was found that the tests recommended by Morgan (1) could be adapted for use on the leaf petioles. Because of the presence in the leaf blade of substances that interfered with both the potassium and the magnesium tests, the fresh or dried leaf blades could not be used unless the procedures were modified. The petiole tissue, however, was quite satisfactory and the tests were developed for use in the field on fresh leaf petioles.

### PROCEDURE

*Collection and Preparation of Samples:*—Composite samples of midshoot leaves with petioles attached are collected from representative trees in the area under study and are tested preferably within a few minutes. The petioles are separated from the leaves and sorted into four or five groups, the petioles in each group being approximately the same length. The upper one-third, that is the part nearest the leaf blade, is cut with a pair of scissors into small pieces not more than 3 mm in length. After the pieces are thoroughly mixed, a level  $\frac{1}{4}$  teaspoonful is placed in a test tube of about 15 mm outside diameter and 150 mm length. A pinch of Darco decolorizing carbon is added and then 10 ml of Morgan's Universal extracting solution. This solution is prepared by adding 100 grams of sodium acetate to 500 ml of distilled water; after dissolving, 30 ml of glacial acetic acid is added and the solution made up to 1 liter. The tubes are shaken for about 2 minutes. The suspensions are then filtered into tubes or vials and the extracts used for the potassium and magnesium tests.

#### *Potassium Test:*—

Reagents (taken from Morgan, 1)

- A. Dissolve 5 grams of  $\text{Co}(\text{NO}_3)_2$  and 30 grams of  $\text{NaNO}_2$  in 50 ml of distilled water acidified with 2.5 ml of glacial acetic acid. Make up to 100 ml with distilled water. Let stand 24 hours and filter.

- B. Isopropyl alcohol, 90 ml, mixed with formaldehyde solution, neutral, 10 ml. (Store in a bottle with a tightly fitting screw cap).

Exactly 5 drops of the extract are transferred to a small glass vial, of about 10 mm inside diameter and 37 mm length, and to this are added exactly 5 drops of the Universal solution, and the vial gently shaken to mix the contents. One drop of potassium reagent A is added and the contents gently shaken, and then 10 drops of reagent B. The contents are allowed to stand for about 1 minute and then shaken gently. After 2 minutes the resulting turbidity is compared with a set of standards prepared as described below under section on standards. All vials, tubes, and so on should be rinsed several times immediately after completion of either the potassium or the magnesium test.

*Magnesium Test:—*

Reagents (from Morgan, 1)

- A. Dissolve 0.10 grams of Titan yellow (Eastman Kodak Company) in a mixture of 50 ml of methylalcohol and 50 ml of distilled water. This should be freshly prepared every 3 or 4 months.

- B. Dissolve 15 grams of sodium hydroxide in 100 ml of distilled water.

Exactly 3 drops of the extract are transferred to a small glass vial and to this are added exactly 7 drops of the Universal solution and the contents shaken gently. One drop of magnesium reagent A is added and the contents shaken gently. Then 3 drops of magnesium reagent B are added and the contents shaken gently. After about 1 minute the color is compared with the standards prepared as described below:

*Standard Solution:—*

A standard solution is prepared by dissolving 0.215 grams  $\text{KNO}_3$  and 0.305 grams of  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  in 1,000 ml of water. This solution contains 100 parts per million of  $\text{K}_2\text{O}$  and 50 parts per million of  $\text{MgO}$ .

*Potassium Standards:—*

Exactly 2, 4, 6, and 8 drops, respectively, of the standard solution are transferred to four small glass vials, and to these are added 8, 6, 4, and 2 drops, respectively, of the Universal solution making a total of 10 drops in each vial. After the contents are shaken gently, the potassium reagents A and B are added and the turbidity developed exactly as described above for the petiole extract. Standard 2 or below represents low potash in the deficiency range and standard 8 represents very high potash. The turbidity changes in a few minutes and a new series of standards has to be made up with every series of tests.

*Magnesium Standards:—*

Exactly 1, 2, 3, 4, and 5 drops, respectively, of the standard solution are transferred to five small glass vials, and 9, 8, 7, 6, and 5 drops, respectively, of the Universal solution are added to make a

total of 10 drops of solution in each vial. After the contents are shaken gently, the magnesium reagents A and B are added and the color developed exactly as described above for the petiole extract. The color of the petiole extract is compared with the standard. One drop of standard represents very low magnesium in the deficiency range and 4 drops very high magnesium. The color fades in these standards in a few minutes and consequently a fresh set of standards has to be made up with every series of tests.

### CORRELATION OF PETIOLE QUICK TEST WITH TOTAL QUANTITATIVE ANALYSIS OF LEAF BLADE

Samples from a number of orchards located on widely different soil types where the nutritional conditions were known were tested in July and August 1946 by the procedure described above. The leaf blades of the same samples were collected and analyzed quantitatively for correlation with the quick tests. The data are given in Table I.

It will be noted that the correlation coefficients, +0.77 for potassium and +0.80 for magnesium, far exceed values required at the .01 level of significance. Almost invariably the potassium and the magnesium

TABLE I—RESULTS OF POTASSIUM AND MAGNESIUM QUICK TESTS ON TUNG PETIOLES AND OF QUANTITATIVE ANALYSES OF LEAF BLADES, AND THEIR CORRELATION (SAMPLES COLLECTED IN JULY AND AUGUST 1946). ANALYSES ON DRY-WEIGHT BASIS

Sample Number	Orchard Location and Condition	Potassium		Magnesium	
		Petiole Quick Test*	Leaf Blade (Per Cent)	Petiole Quick Test†	Leaf Blade (Per Cent)
1	Brooker, Fla., normal	3	1.02	3	0.36
2	Brooker, Fla., normal	3	1.04	3	0.37
3	Brooker, Fla., Mg-deficient	8	1.66	2	0.22
4	Brooker, Fla., Mg-deficient	8	1.66	2	0.18
5	LaCrosse, Fla., low K	2	0.58	4	0.69
6	LaCrosse, Fla., normal	5	0.84	3	0.45
7	LaCrosse, Fla., low K	2	0.62	4	0.67
8	LaCrosse, Fla., low K	2	0.69	4	0.54
9	Monticello, Fla., K-deficient	1	0.44	4	0.56
10	Monticello, Fla., normal	5	0.81	3	0.34
11	Monticello, Fla., K-deficient	2	0.51	5	0.67
12	Monticello, Fla., normal	6	0.84	4	0.47
13	Monticello, Fla., low K	4	0.59	3	0.37
14	Lloyd, Fla., normal	6	0.70	4	0.43
15	Lloyd, Fla., normal	5	0.96	3	0.41
16	Lloyd, Fla., normal	6	0.88	4	0.39
17	Lloyd, Fla., normal	5	0.79	4	0.42
18	Lloyd, Fla., normal	6	0.88	3	0.35
19	Lloyd, Fla., K-deficient	2	0.41	4	0.68
20	Lloyd, Fla., normal	5	0.93	3	0.44
21	Lloyd, Fla., Mg-deficient	6	1.11	1	0.12
22	Cairo, Ga., Mg-deficient	5	0.99	1	0.16
23	Quincy, Fla., Mg-deficient	5	1.07	1	0.23
24	Quincy, Fla., low K	2	0.74	3	0.41
25	Quincy, Fla., Mg-deficient	6	1.14	2	0.13
26	Cairo, Ga., Mg-deficient	6	1.37	1	0.18
27	Cairo, Ga., normal	3	0.80	3	0.40
28	Cairo, Ga., K-deficient	2	0.66	4	0.38
Correlation coefficient.....		0.77		0.80	
Correlation coefficient required for significance at 0.05 = 0.38					
Correlation coefficient required for significance at 0.01 = 0.48					

\*Drops of standard, in range from 1 = very low K, to 8 = very high.

†Drops of standard, in range from 1 = very low Mg, to 5 = very high.

deficiencies, as indicated by the analyses of the leaf blades, are reflected in low test readings on the petioles. As has been found with other crops, a low magnesium content of the leaf tissue is usually accompanied by a high potassium content and *vice versa*. This fact provides a means of confirming the diagnosis of potassium or of magnesium deficiency by testing for both elements.

The primary objective in developing these tests was to be able to differentiate quickly between magnesium-deficient and potassium-deficient areas while in the field. It may be possible to refine the tests further so as to be able to designate low, medium, and high levels, but this was beyond the scope of the present investigation.

#### DIFFERENCE IN COMPOSITION OF DIFFERENT PARTS OF TUNG LEAF PETIOLES

In the preliminary trials it was found that different portions of the petiole gave different results. To get more specific information on this point, leaf samples with the petioles attached were collected in the usual manner in July and August 1946 from several orchards on different soil types. The petioles were separated from the leaves and divided into three sections approximately equal in length; (a) top (nearest blade); (b) middle; and (c) bottom (adjacent to twig). The three parts of the petiole and the leaf blade were analyzed quantitatively for N, P, K, Ca, and Mg. The data, on dry-weight basis, are given in Table II.

TABLE II—MINERAL COMPOSITION OF TOP, MIDDLE, AND BOTTOM SECTIONS  
OF TUNG LEAF PETIOLES, AND OF LEAF BLADES, ON DRY-WEIGHT BASIS

Orchard Location	Plant Part	K (Per Cent)	Mg (Per Cent)	Ca (Per Cent)	P (Per Cent)	N (Per Cent)
Brooker, Fla.	Top of petiole	1.92	0.87	3.03	0.37	0.48
	Middle of petiole	1.29	0.40	2.23	0.21	0.43
	Bottom of petiole	1.61	0.69	2.44	0.26	0.48
	Leaf blade	1.02	0.36	1.91	0.16	2.20
Brooker, Fla.	Top of petiole	3.54	0.50	2.21	0.19	0.59
	Middle of petiole	2.62	0.18	1.50	0.10	0.50
	Bottom of petiole	2.75	0.30	1.58	0.12	0.50
	Leaf blade	1.66	0.22	0.98	0.16	2.64
LaCrosse, Fla.	Top of petiole	0.37	1.26	2.40	0.30	0.42
	Middle of petiole	0.26	0.62	2.09	0.14	0.35
	Bottom of petiole	0.36	0.95	2.19	0.19	0.40
	Leaf blade	0.62	0.67	2.79	0.14	1.54
LaCrosse, Fla.	Top of petiole	1.14	0.98	2.75	0.26	0.42
	Middle of petiole	0.66	0.49	2.27	0.13	0.36
	Bottom of petiole	0.68	0.76	2.39	0.16	0.41
	Leaf blade	0.84	0.45	2.78	0.13	1.60
Monticello, Fla.	Top of petiole	0.47	1.09	3.42	0.30	0.48
	Middle of petiole	0.19	0.38	2.72	0.12	0.46
	Bottom of petiole	0.26	0.67	3.06	0.18	0.52
	Leaf blade	0.44	0.56	3.10	0.15	2.17
Monticello, Fla.	Top of petiole	1.89	0.87	3.98	0.29	0.49
	Middle of petiole	1.20	0.44	2.98	0.16	0.43
	Bottom of petiole	1.28	0.63	3.47	0.16	0.45
	Leaf blade	0.84	0.47	3.64	0.15	2.14
Average all locations	Top of petiole	1.56	0.93	2.97	0.30	0.48
	Middle of petiole	1.04	0.42	2.30	0.14	0.42
	Bottom of petiole	1.15	0.67	2.52	0.18	0.46
	Leaf blade	0.90	0.46	2.53	0.15	2.05

A surprising feature of these analyses is the distribution of certain elements between the different parts of the petiole. This indicates the necessity in diagnostic work of always using the same part of the petiole for comparative purposes. Almost invariably, with all the elements except nitrogen, the section of the petiole nearest the leaf blade is highest in mineral content, the middle portion lowest, and the bottom intermediate. In the case of magnesium and phosphorus, the top of the petiole has at least twice as much as the adjacent middle portion. With potassium, the difference is not quite so striking, and with calcium, still less so; but the same general relationship holds between the three portions of the petiole. The large differences in composition between different parts of the petiole, and the fact that the middle portion is lowest, is difficult to understand. Undoubtedly there are morphological differences between the parts which might throw some light on this question.

The relation of the composition of the petiole parts to that of the leaf blade varies with the different elements, and also with the same element at different levels of content. When the general level of potassium is high, the potassium content of the top of the petiole is considerably higher than, in some cases as much as double, that of the leaf blade; and that of the other parts of the petiole usually exceeds that of the leaf blade. When the over-all potassium content is low, however, the leaf blade is as high as or higher in potassium than any part of the petiole. The top of the petiole, therefore, has a much greater range in potassium content than the leaf blade.

In the case of magnesium, both the top and the bottom of the petioles are higher than the leaf blade at all levels of magnesium. The middle of the petiole usually approximates the leaf blade in magnesium content. Except in one instance this holds true for phosphorus also. With calcium, the relationship between leaf blade and petiole is not well defined, and, in the case of nitrogen, there is four to five times as much nitrogen in the leaf blade as in the petiole. There is not much difference in nitrogen content of the three parts of the petiole.

The correlation coefficients for the percentages of the various elements in the leaf blade with those in the different parts of the petiole were determined from data on 12 groups of samples, six of which are not shown in Table II. For potassium the correlation coefficients were +0.97, +0.98, and +0.98 for the top, middle, and bottom sections of the petiole, respectively. These far exceed values required at the .01 level of significance. For magnesium the coefficients were +0.97, +0.90, and +0.94 for the top, middle, and bottom parts of the petiole, respectively, and these also far exceed values required at the .01 level of significance. These results indicate that the petioles could be used satisfactorily in the quick tests instead of the leaf blade as a measure of the levels of potassium and magnesium. The test was standardized for the top section of the petiole, because it has the widest range in composition.

For nitrogen, the correlation coefficients between the petiole parts and the leaf blade were +0.91, +0.86, and +0.90 for the top, middle, and bottom parts of the petiole, respectively. Although these values



exceed the .01 level of significance, the usefulness of these correlations is limited because of the small range and low percentages of nitrogen in the petiole in comparison with the leaf blade.

For phosphorus, the correlation coefficients were +0.40, +0.86, and +0.38 for the top, middle, and bottom parts of the petiole. Only the coefficient for the middle section attains statistical significance. This situation is difficult to interpret and perhaps merits further attention.

For calcium, the correlation coefficients were +0.63, +0.86, and +0.82 for the top, middle, and bottom parts of the petiole respectively. The first is statistically significant at the .05 level and the latter two at the .01 level.

#### SUMMARY

A quick tissue test for potassium and magnesium deficiencies in tung is described in which Morgan's reagents are used with fresh leaf petioles. Data are presented showing a highly significant correlation between the quick test determinations of potassium and magnesium and the quantitative analyses of the leaf blades.

The top, middle, and bottom sections of the petiole differed greatly in composition. In all elements except nitrogen the top of the petiole (nearest the leaf blade) was highest in percentage composition on dry weight basis, the middle lowest, and the bottom intermediate. The relation of the composition of the petiole parts to that of the leaf blade varied for the different elements and even for different levels of the same element, but in general there was a high positive correlation.

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## Effects of Nitrogen, Phosphorus, and Potassium on Growth and Yield of Tung Trees and Composition of Fruits

By GEORGE M. BAHRT and GEORGE F. POTTER, *U. S. Department  
of Agriculture, Bogalusa, La.*

**I**N the fall of 1940 an experiment was inaugurated in a 6-year-old seedling tung orchard on Red Bay fine sandy loam soil near Lucedale, Mississippi, to determine some of the effects of nitrogen, phosphorus, and potassium on the growth and production of tung trees and on the oil content of the fruit.

The trees, planted 25 feet apart each way, were arranged in 108 plots of six trees each, the individual plots being separated by appropriate guard rows. In the fall of 1941, 500 pounds per acre of basic slag was applied to all plots at the time of seeding a winter cover crop of vetch. In 1942 and succeeding years, no cover crop was planted, but a blanket application of 200 pounds per acre of 20 per cent superphosphate was made on the volunteer native vegetation and crotalaria. When turned under the cover crop returned to the soil the phosphorus and other food materials that it absorbed from the basic slag or the superphosphate or from the soil, and in addition the nitrogen fixed by the vetch and volunteer legumes. The amounts thus made available to the trees constituted the low level of each element in this experiment. Beginning in 1941 supplementary applications were made annually in March to establish intermediate and high levels of each of the three elements. For the intermediate level the amounts applied per acre were: nitrogen, 18 pounds of N, one-third as sodium nitrate and two-thirds as sulphate of ammonia; phosphorus, 18 pounds of  $P_2O_5$ , as superphosphate; potassium 13.5 pounds  $K_2O$  as muriate. For the high level twice these amounts were applied. Each level of each element was used alone and in all possible combinations with different levels of the other two elements, making a total of 27 treatments, which were set up in four replications. The 27 treatments were distributed at random within replications.

From 1941 to 1944, the fertilizers were broadcast over the whole area of the orchard. Subsequent to the initiation of this experiment, Bahrt (1) found that applying the fertilizer in a band beneath the spread of the branches was more effective than broadcasting, and this method was adopted for the spring applications beginning in 1945. In August 1942, 16 samples of leaves were taken, two from each of the eight treatments representing all possible combinations of the high and low levels of each element. For each treatment, one sample was composited from replications I and II and the other from replications III and IV. The same eight treatments were sampled in August in 1943, 1944, and 1945, by taking each of the four replications separately, making a total of 32 samples. In all cases, each sample consisted of 48 to 50 midshoot leaves from shoots of modal length, in representative positions on four sides of each tree in the plot or plots.

In both 1943 and 1944 representative samples of 100 fruits, consist-

ing of approximately an equal number from every tree, were taken from each plot, so far as available. Owing to frost injury to the crop in 1943, only 62 samples could be collected that season; 108 samples were taken in 1944. The moisture content of the fruit was brought to equilibrium with a saturated solution of calcium chloride. The fruits were then divided into their component parts, and analyzed<sup>1</sup> for oil content as described by Potter *et al* (3).

## RESULTS

In this experiment one-third of the total number of trees received the low level of nitrogen, another third the intermediate level, and the remaining third the high level, all three groups having received comparable amounts of phosphorus and of potassium. Similarly the orchard can be divided into another set of three groups according to level of phosphorus applied, all three groups having received comparable amounts of nitrogen and potash. Finally, a similar division can be made according to level of potassium, with comparable amounts of nitrogen and phosphorus. Statistical analyses of the data on growth and production of trees and composition of the fruit showed no significant interactions between the three elements applied. The responses to each element can therefore be studied most precisely as averages for the three sets of groups outlined above.

*Leaf Composition:*—The data,<sup>2</sup> which are given in Table I, indicate that the application of nitrogen were reflected in leaf composition as

TABLE I—EFFECTS OF FERTILIZERS ON THE NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF TUNG LEAVES SAMPLED IN AUGUST (DRY BASIS)

Year	Samples (No.)	Constituents in the Leaves										
		Nitrogen as N			Phosphorus as P			Potassium as K		F Required At		
		Rate of Ap- plication (Per Cent)		F Found	Rate of Ap- plication (Per Cent)		F Found	Rate of Ap- plication (Per Cent)		F Found	0.05 Level	0.001 Level
		Low	High		Low	High		Low	High			
1942	16	1.23	1.62	1.16	0.11	0.11	—	0.91	0.87	*	3.79	7.00
1943	32	1.62	2.32	14.89	0.13	0.14	7.25	0.85	0.97	2.14	2.49	3.65
1944	27†	1.96	2.28	—	0.13	0.15	—	0.81	1.09	—	—	—
1945	32	1.79	2.08	5.81	0.15	0.19	12.50	0.72	0.98	6.37	2.49	3.65

\*Mean square for treatments lower than mean square for error.

†Five samples lost. Readings computed from 27 plots but data not analyzed statistically.

early as 1942 and 1943. The response to applications of phosphorus and potassium occurred more slowly, but ultimately substantial differences due to fertilization were observed.

<sup>1</sup>The writers are indebted to A. J. Loustalot, assistant plant physiologist (resigned), and S. G. Gilbert, associate plant physiologist, U. S. Field Laboratory for Tung Investigations, Gainesville, Florida for the oil analyses.

<sup>2</sup>The writers are indebted to Dr. Matthew Drosdoff, soil technologist, U. S. Field Laboratory for Tung Investigations, Gainesville, Florida for the leaf analyses.

*Response to Nitrogen:*—Potter, Kilby, and Bahrt (2) have published data showing that applications of nitrogen have had a negligible effect on the size of individual tung fruits, and unpublished data from rather extensive experiments indicate that the same is true for phosphorus and potash. Also, observations covering a period of years indicate that the percentage set of pistillate tung flowers is ordinarily so high that it is not influenced appreciably by fertilizer applications. Hence the crop of 1941 reflects the yield of fruit before the differential fertilizers were applied. The crop of 1943 was almost wholly destroyed by frost. The additional nitrogen applied produced rather substantial responses in yield in 1942 and 1944 (Table II). It is believed that the low yield of 1945 was due to the biennial bearing tendency in tung, which has been described by Potter, Sitton, and McCann (4), and which would tend to restrict production in 1945 on those trees that bore most heavily in 1944. Considering the whole period, the higher the level of nitrogen, the higher the yield. The average yields for four years, 1942 to 1945, were 10.4, 15.2, and 19.1 pounds of air dry fruit per tree for low, intermediate, and high levels of nitrogen, respectively (Table II). These increases in yield have very high statistical significance. These data support those previously reported (2, 5).

TABLE II—EFFECTS OF LEVELS OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON GROWTH AND YIELD OF TUNG TREES

Fertilizer Element	Level	Gain in Cross-Sectional Area of Trunk 1940-1945 (Sq In)	Average Yields Air Dry Fruit Per Tree (Lbs)					Average 1942 to 1945 (Lbs)
			1941	1942	1943	1944	1945	
Nitrogen	Low	20.7	2.7	12.3	0.9	13.8	14.7	10.4
	Intermediate	25.9	3.1	15.1	1.0	27.9	16.9	15.2
	High	31.2	2.7	17.8	1.7	39.2	17.9	19.1
F found		26.11	*	7.51	3.51	27.33	4.26	24.43
Phosphorus	Low	25.0	2.6	15.7	1.1	26.2	15.0	14.5
	Intermediate	24.9	2.5	13.2	1.4	25.1	16.4	14.0
	High	27.8	3.4	16.2	1.2	29.6	18.0	16.3
F found		2.58	3.22	2.57	*	*	3.49	1.82
Potassium	Low	25.6	2.9	15.5	1.5	29.4	16.2	15.7
	Intermediate	24.9	2.7	14.4	1.1	27.0	16.6	14.8
	High	27.2	2.8	15.3	1.1	24.5	16.6	14.4
F found		1.30	*	*	*	1.02	*	*

\*Mean square for treatment less than mean square for error.

F required for 0.05 level 3.11

F required at 0.01 level 4.88

The data in Table II show that the gains in cross-sectional area of the trunks for the period 1940 to 1945 inclusive, were 20.7, 25.9, and 31.2 square inches, respectively, for the low, intermediate, and high levels of nitrogen. These differences are supported by an observed value of F of 26.11 where 7.76 is required for significance at the .001 level. Since the gain in cross-sectional area of the trunks of the trees at the high level of nitrogen was 50.7 per cent greater than that at the low level, it is evident that a considerable proportion of the increase in yield is due simply to size of tree.

Data on composition of the fruit (Table III) show that nitrogen produced a statistically significant decrease in percentage of oil in the kernel and a tendency toward a higher percentage kernel in the whole

TABLE III—EFFECTS OF LEVELS OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON COMPOSITION OF TUNG FRUITS\*

Fertilizer Element	Level	Kernel in Whole Fruit (Per Cent)		Oil in Kernel (Per Cent)		Oil in Whole Fruit (Per Cent)	
		1943	1944	1943	1944	1943	1944
Nitrogen	Low	30.7	30.0	65.1	64.9	20.1	19.5
	Intermediate	30.8	30.8	62.6	63.3	19.3	19.5
	High	31.5	31.7	61.6	62.0	19.4	19.6
F found		†	9.39	8.42	51.26	†	†
Phosphorus	Low	31.0	30.5	62.9	63.2	19.6	19.3
	Intermediate	31.6	31.0	63.5	63.5	20.2	19.7
	High	30.4	31.0	62.5	63.4	19.0	19.6
F found		1.31	†	1.04	1.41	1.56	3.21
Potassium	Low	30.2	31.1	61.9	62.8	18.7	19.5
	Intermediate	31.4	30.9	64.0	63.8	20.1	19.7
	High	31.8	30.5	63.8	63.6	20.3	19.4
F found		2.29	†	3.38	5.11	3.14	1.06

\*Owing to loss of crop from frost injury, only 62 samples could be collected in 1943. The analysis used requires an F value of 3.17 at 0.05 and 5.01 at 0.01. In 1944, 108 samples were collected and F values of 3.11 at 0.05 and 4.88 at 0.01 are required.

†Mean square for treatment lower than mean square for error.

fruit, but no appreciable effect on oil in the whole fruit. In an experiment on Ora soil at Bush, Louisiana, similar in design but with wider differences in levels of fertilizers, Sitton and Loustalot (5) found that nitrogen increased the percentage of kernel to such an extent as to outweigh the loss in percentage of oil in the kernel and so effect a net gain in oil in the whole fruit.

*Response to Phosphorus*.—It was previously pointed out that yields in 1941 were dependent on the number of pistillate flowers formed in 1940, before differential fertilizing was begun, yet there was an apparent response to phosphorus that year (Table II). This is interpreted to mean that, although treatments were assigned at random, by coincidence the plots that received the high level of phosphorus either occupied an advantageous position in the field or they happened to have the best individual trees. If this is true, then there was no response in growth, yield, or composition of the fruit that can be attributed to phosphorus. The lowest level of phosphorus applied, that necessary to insure a satisfactory cover crop, was adequate for the trees. The additional phosphorus absorbed at the higher rates of application was evidently luxury consumption.

*Response to Potassium*.—Potassium produced no significant differences in cross-sectional area of the trunks, and as an average for the 4-year period higher yields were obtained from the plots receiving no potassium than from those to which the intermediate and high amounts were applied, but the differences are without statistical significance (Table II). However, the percentage of oil in the kernel was

increased both years, and trends toward increased percentages of kernel in the whole fruit and of oil in the whole fruit were observed at the intermediate and high levels of potassium in 1943, but not in 1944. That the application of potassium usually increases percentage kernel and percentage oil in the whole fruit has been shown by Potter *et al* (3) and also by unpublished data from other similar experiments.

#### SUMMARY

Nitrogen significantly increased trunk cross-sectional area of tung trees, yield of fruit, and percentage of kernel in the whole fruit, but decreased the oil content of the kernel significantly. Percentage of oil in the whole fruit was not affected.

Although the additional increments of phosphorus applied were absorbed by the tree in amounts that finally increased the phosphorus content of the leaves appreciably, no response was observed in growth, production, or composition of the fruit. The lowest level of phosphorus applied, that necessary for production of a satisfactory cover crop, was adequate for the trees.

Potassium had no significant effect on growth or yield, but increased the oil content of the kernel, and in 1943 also improved the kernel content of the fruit and percentage of oil in the whole fruit.

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## A Comparison of Winter and Spring Applications of Ammonium Nitrate to Tung Trees

By ELWOOD G. FISHER, FELIX S. LAGASSE, and JUDSON H. LASSITER, *U. S. Department of Agriculture, Gainesville, Fla.*

A STUDY (1) conducted during the winter and spring of 1944-45 indicated that ammonium nitrate applied to tung trees as early as December and January was absorbed in part by the roots within about 30 days and was transported to the growing points previous to the time growth started in the spring. Also it appeared that the trees fertilized early in the winter had made better growth by June 26, 1945, as indicated by shoot weight and length and number of leaves per shoot, than trees fertilized later. The experiment was continued during the winter of 1945-46 and further observations on growth and composition are reported herewith.

### MATERIALS AND METHODS

As reported previously, the experiment was conducted with seedling tung trees, seven years old when the work was begun in December 1944, growing on a Norfolk fine sandy soil near Brooker, Florida. The 1945-46 treatments consisted of 5 pounds of ammonium nitrate per tree applied at different dates as follows: December 29, 1945; January 24, 1946; February 18, 1946; and March 18, 1946. Each treatment was applied to single tree plots in nine replications. These treatments were supplemental to the grower's fertilizer, which consisted of 9 pounds of 7-4-5 per tree applied about April 1, 1946.

On July 3, 1946, samples, each consisting of 10 bearing terminals of 1945 with all the 1946 growth produced thereon, were taken at random from each tree. These were fractionated into (a) leaves, (b) petioles, (c) fruits, (d) 1946 shoots, and (e) 1945 twigs. The fruits and 1946 shoots were counted, the shoots were measured and dry weight and percentage of total nitrogen in each component were determined. Since the 10 terminals taken for chemical analysis constitute a rather small sample to represent accurately the average terminal growth of the trees, the total shoot growth on an additional 36 terminals was measured in August 1946. Fibrous roots located within 8 to 10 inches of the soil surface were obtained from four sides of each tree. Roots from the nine trees in each treatment were composited into three samples, one from replications I to III, another from replications IV to VI, and the third from replications VII to IX inclusive.

### RESULTS

Data on the effect of the supplemental application of ammonium nitrate on growth and the nitrogen content of the terminals, leaf blades, petioles, and fruits, as of July 3, 1946, are shown in Table I and also a summary of the shoot measurements made in August 1946. All trees that received the supplemental application of 5 pounds of ammonium nitrate exceeded the check trees in shoot growth, number of leaves per terminal, and in dry weight of leaves, petioles and shoots.

TABLE I.—TREATMENT AVERAGES OF 1946 GROWTH PRODUCED PER 1945 TERMINAL (JULY 3, 1946)

5 Pounds NH <sub>4</sub> NO <sub>3</sub> (Date Applied)	Dry Weight of 1946 Growth				Total Nitrogen				Weight of Nitrogen				Total 1946 Growth (Mgs)	Length of Shoot Growth (Cm)	Supplemen- tary Terminal Growth Meas- urements Aug 1946 (Cm)	Shoots per 1945 Terminal (Number)	Leaves per Shoot (Number)	Rainfall Between Treat- ments (Inches)††
	Leaves (Gms)	Petioles (Gms)	Shoots (Gms)	Fruit (Gms)	Leaves (Per Cent)	Petioles (Per Cent)	Shoots (Per Cent)	Fruit (Per Cent)	Roots (Per Cent)	Leaves (Mgs)	Petioles (Mgs)	Shoots (Mgs)	Fruit (Mgs)					
Dec 29, 1945, . . . . .	30.6	1.9	6.4	22.9	2.64	0.64	0.76	1.33	1.87	809	12	48	298	52.0	33.5	2.6	32.9	—
Jan 24, 1946, . . . . .	26.7	1.6	4.4	22.0	2.71	0.62	0.81	1.37	2.09	730	9	36	299	37.5	31.2	2.0	23.4	2.44
Feb 18, 1946, . . . . .	27.5	1.6	5.3	21.0	2.64	0.63	0.79	1.37	1.96	731	10	41	283	42.2	28.6	2.2	25.8	1.12
Mar 18, 1946, . . . . .	26.4	1.5	5.1	20.0	2.76	0.66	0.82	1.47	2.08	735	10	41	295	38.7	32.9	2.0	27.5	3.42
Check—No addi- tional fertilizer	20.1	0.9	3.3	20.0	2.52	0.61	0.76	1.16	1.77	508	6	25	235	29.0	21.9	1.8	21.0	—
F Value* . . . . .	3.35	3.88	3.98	1.72	2.83	2.23	1.89	12.01	9.76†	4.01	4.18	4.17	0.31	5.58	1.23	5.69	7.47	—
Least significant difference at 5 per cent com- paring Decem- ber applica- tion** . . . . .	6.56	0.56	1.74	N.S.†	0.18	N.S.	N.S.	0.11	0.04	180	3.69	13	N.S.	10.74	13.63	0.37	4.99	—
Least significant difference at 5 per cent for all other compar- isons . . . . .	5.79	0.50	1.54	N.S.	0.16	N.S.	N.S.	0.09	0.04	159	3.26	11	N.S.	9.47	12.03	0.33	4.41	—

\*For significance: 5 per cent F = 2.69 and 1 per cent F = 3.86.

\*\*Two trees of the December treatment died, thus comparisons with the December treatment require a greater mean difference.

†For significance: 5 per cent F = 3.34 and 1 per cent F = 7.01 using 3 composites of 3 trees each.

††For nearest record station at Gainesville, Florida.

‡N.S. = Not significant.



The components of the fertilized trees also tended to have a higher nitrogen content than those of the check trees, both on a percentage basis and as milligrams per plant part, although some of the differences failed to attain statistical significance. The effect of the time of applying the supplemental ammonium nitrate appears to be of relatively little importance. The trees to which this material was applied in December tended to have the best growth and the greatest nitrogen content on the basis of weight per plant part, but the differences observed are less pronounced than those reported for the previous season, and in most instances do not attain statistical significance.

The roots of the trees receiving the ammonium nitrate in December were lower in percentage of nitrogen on July 3 than those of any other trees except the checks, a condition similar to that previously reported for April 26, 1945. This may be due to earlier translocation of the nitrogen to the top or earlier utilization by the tree.

In this orchard in 1945-46, tung trees, even in a rather sandy soil, were able to utilize nitrogen applied in December or January just as effectively as that applied at the conventional time from mid-February to mid-March. Tung growers, especially those who are engaged in extensive operations, find it advantageous to begin to fertilize their orchards rather early in the winter, rather than to attempt to complete the whole job during a short period at about the time that the trees start growth. The evidence presented here supports that previously reported and suggests that applications may be made in December and January without undue risk. However, this experiment was on a rather limited scale and more extensive tests, therefore have been set up to obtain further evidence on early winter fertilization. In some of the tung growing areas of the southeastern United States, winter rainfall is much heavier than at Gainesville, Florida. In such locations early winter applications of fertilizer would be more likely to result in loss by leaching, unless the trees were growing in soils having a high base exchange capacity.

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# On the Bearing Behavior of the Kaki Persimmon (*Diospyros kaki*)

By R. W. HODGSON and C. A. SCHROEDER, *University  
of California, Los Angeles, Cal.*

**B**OTH the Japanese and American literature contain numerous references to the alternate or biennial bearing tendency which characterizes certain varieties of the kaki or Oriental persimmon (1, 2). The first published data which depict this tendency in the United States appear to be those obtained by the senior author in another connection (3). In this study it was noted that 38 of the 53 trees of the Hachiya variety, or 70 per cent, whose yield records were reported had exhibited perfect alternation in bearing behavior during the period in question.

The establishment in 1930 of what was probably one of the largest collections of kaki persimmon varieties in the United States within a few years provided an unparalleled opportunity to obtain a general view of the bearing behavior of the species as a whole. The necessity for the removal of this collection in the winter of 1945 terminated the studies in question, which have been resumed elsewhere, and is considered to justify the presentation of a report at this time.

## MATERIALS

The data employed in this study were obtained from 94 trees in a variety collection established at the Citrus Experiment Station, Riverside, California, in March, 1930. This collection originally consisted of 193 trees, all on the lotus rootstock (*Diospyros lotus*), representing 69 accessions and approximately 50 varieties, mainly introductions from China and Japan made by the United States Department of Agriculture. The keeping of detailed yield records, in numbers of fruits per tree, was begun with the 1939 crop in connection with studies previously undertaken on floral situation, sex condition and parthenocarp (4). These studies were concluded with the crop of 1945, at which time there remained in the collection the 94 trees in question on which yield records were available for the full period of the study, the others having progressively been removed to eliminate pollen sources and resultant fruit seediness. As a consequence the 41 accessions and 25 varieties whose bearing behavior is here reported are almost certainly all pistillate forms.

During much the greater part of the period of this study, however, pollen sources scattered through the planting resulted in more or less seediness throughout. Moreover, comparison of the bearing behavior of the trees which regularly produced staminate flowers, and hence seedy fruits, strongly suggests that the 94 trees employed in this study comprise a representative sample for the group as a whole.

## DATA AND RESULTS

Limitations of space preclude the presentation of the individual tree yield records. Upon analysis, however, it has been found that they fall

into four groups with reference to bearing behavior for the 7-year period of record, 1939 to 1945. The average yields, in number of fruits per tree, for these groups and for the 94 trees as a whole are shown in Table I, and their bearing behavior in Fig. 1.

TABLE I—AVERAGE YIELDS OF PERSIMMON TREES, 1939–1945  
(NUMBER OF FRUITS PER TREE)

1939	1940	1941	1942	1943	1944	1945
<i>Group 1 (36 Trees)</i>						
109.5	653.6	74.9	592.4	98.3	528.3	180.1
<i>Group 2 (22 Trees)</i>						
161.1	46.5	202.6	34.9	234.6	38.2	151.9
<i>Group 3 (19 Trees)</i>						
87.8	370.0	90.8	263.1	244.6	145.1	288.8
<i>Group 4 (17 Trees)</i>						
163.1	313.4	186.4	146.4	205.0	320.5	225.5
<i>All Groups Together (94 Trees)</i>						
126.9	392.3	128.2	314.7	179.1	300.2	203.7

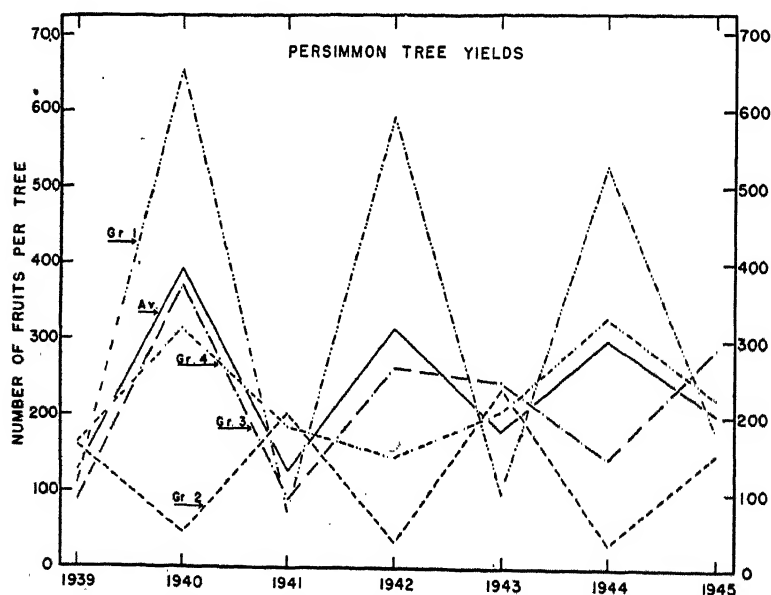


FIG. 1. Bearing behavior of 94 Oriental persimmon trees; average for the group as a whole, and for each of the four sub-groups of similar bearing behavior.

*Group 1:*—This group consists of 36 trees (38.3 per cent) which alternated perfectly throughout the period, starting in the "off"-crop phase in 1939 and ending in that phase in 1945.

*Group 2:*—This group contains 22 trees (23.4 per cent) which likewise alternated perfectly throughout the period but in opposite phase to the trees in group 1.

A total of 58 trees (61.7 per cent), therefore, exhibited perfect alternation throughout the 7-year period. In this connection it will be recalled that 70 per cent of the Hachiya trees reported on by the senior author (3) alternated perfectly for a somewhat shorter period. Examination of the data in question reveals that these trees likewise consisted of two groups in opposite phases of alternation.

*Group 3:*—This group consists of 19 trees (20.2 per cent) which alternated in bearing for 6 of the 7 years, having changed stride of alternation once during that period. The greater part of them were similar to the trees in group 1 for the first 5 years but then changed stride. The others were similar to the trees in group 2 at the outset but changed stride shortly thereafter. The influence of the former was dominant for the group as a whole.

Examination of the individual records of the trees comprising this group shows that in every case the change in stride of alternation followed the production of a crop intermediate in size between the amplitude of alternation exhibited up to that time.

*Group 4:*—This group contains 17 trees (18.1 per cent) whose bearing behavior did not exhibit any consistent pattern for the period in question. Some of these tended to alternate part of the time but changed stride twice during the period. Others showed little if any tendency toward alternate bearing.

*All Groups Together:*—The pattern of alternate bearing behavior exhibited by the four groups averaged together is undoubtedly the result of the dominance of groups 1 and 3, which comprise 58.5 per cent of the total and in which, for unknown reasons, the amplitude of alternation was greatest.

*Varietal Behavior:*—Examination of the individual tree yield data discloses the fact that 19 of the 25 varieties (76 per cent) exhibited perfect alternation (groups 1 and 2) in part or all of the trees represented. Twelve of these contained trees in group 1, three contained trees in group 2, and four had trees in both groups 1 and 2. Four varieties consisted only of trees in group 3 and two had trees only in group 4. Two of the four varieties in group 3 were represented by one tree each and both varieties in group 4 consisted of one tree each. It therefore appears that 23 of the 25 varieties (92 per cent) represented in this study have clearly exhibited the alternate bearing tendency.

#### DISCUSSION AND CONCLUSIONS

Attention should be directed to the fact that the amplitude of alternation in bearing behavior exhibited by the trees employed in this study is actually considerably less than that indicated by the data herein reported. This arises from the fact that the yield records were recorded in number of fruits per tree rather than in weight of crop. On many trees, notably those in which alternation was most pronounced, average fruit size was considerably smaller in the large crops than in the small crops. As a consequence the differences were less

than the data indicate, but by no means sufficient to cast doubt on the validity of the conclusions drawn. Indeed, examination of the individual tree yield data reveal numerous instances of complete failure to bear following excessively large crops. While the data are insufficient to permit of the drawing of conclusions, they suggest that the alternate bearing tendency is more marked in certain varieties than in others.

From the similarity in bearing behavior exhibited by groups 1 and 3 for much the greater part of the period of this study, and the fact that together they comprise nearly 60 per cent of the total, the conclusion seems warranted that at least half of the trees in this study set their first crops large enough to initiate the alternate bearing tendency in the same year and continued to alternate with pronounced regularity thereafter. Evidently, however, a considerable number, represented by group 2, did not reach that condition until a year later, from which time on they too have continued to alternate with pronounced regularity, though with less amplitude in alternation. Collectively these three groups have comprised 81.9 per cent of the total.

It may also be noted that the alternate bearing tendency herein established is markedly similar to that reported for the Fuerte avocado (5), the Valencia orange (6) and the loquat (7).

From this study it is concluded that the tendency toward alternate bearing behavior is strongly marked in horticultural varieties of the Oriental or kaki persimmon (*Diospyros kaki*).

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## Rootstock Influence on Fruit-Set in the Hachiya Persimmon

By C. A. SCHROEDER, *University of California, Los Angeles, Cal.*

THE Hachiya variety of the Oriental persimmon (*Diospyros kaki*) when grown in California exhibits continuous dropping of immature fruit during the season (1). Abundant field and experimental evidence (3) indicates that in California all varieties of the Oriental persimmon set and develop fruit parthenocarpically; hence inadequate pollination cannot be the reason for the observed heavy dropping of immature fruits. The tendency for Hachiya, the most important commercial variety in California, to shed a large percentage of its fruit prematurely when grown on *D. lotus* rootstock has been noted (2). As to whether the small crops of Hachiya grown on *D. lotus* rootstock result from a smaller flower crop or from a relatively heavier shed of immature fruit has not been determined thus far, however.

The objective of the present investigation was to ascertain the facts as to the quantity of blossom production and fruit shed in the Hachiya persimmon as related to the common rootstocks on which it has been propagated.

### METHODS AND MATERIALS

Single trees of Hachiya on each of the three rootstocks *Diospyros kaki*, *D. lotus* and *D. virginiana* were propagated and planted in the Subtropical Horticulture orchard at Los Angeles in 1934. The trees were among those used in an earlier study (2). They were of good size and in good health. The Hachiya-*D. kaki* combination bears a satisfactory commercial crop.

Collections and records were made of all blossoms and fruits shed and matured in the two seasons 1945 and 1946. Two years of data were obtained so that alternation of bearing behavior might be detected if it occurred.

### DATA AND DISCUSSION

A tendency for the variety Hachiya to alternate in its bearing irrespective of the rootstock on which it grows is observed in Table I. The marked reduction in annual and total yield on *Diospyros lotus* rootstock compared with *D. kaki* is evident, although both trees are of approximately the same size and presumably have about equal bearing surfaces. Hachiya grown on *D. virginiana*, however, is a distinctly smaller tree and is included in the study primarily for comparison.

TABLE I—YIELD IN FRUITS HACHIYA PERSIMMON

Rootstock	1940	1941	1942	1943	1944	1945	1946	Total
<i>Diospyros kaki</i> .....	71	118	213	110	86	274	157	1,029
<i>Diospyros lotus</i> .....	19	4	16	33	6	81	68	227
<i>Diospyros virginiana</i> .....	3	0	39	21	3	44	36	146

Total blossom and fruit production for the seasons 1945 and 1946 are given in Table II. It will be observed that Hachiya on *Diospyros*

*lotus* produced more blossoms (5.4 and 12.1 per cent respectively), but matured less fruit (70.5 and 56.8 per cent respectively) during this two year period when compared with Hachiya grown on *D. kaki*.

TABLE II—NUMBER OF FLOWERS AND MATURE FRUITS  
HACHIYA PERSIMMON

Rootstock	1945			1946		
	Total Flowers	Total Fruit	Per Cent of Flowers Which Matured as Fruit	Total Flowers	Total Fruit	Per Cent of Flowers Which Matured as Fruit
<i>Diospyros kaki</i> .....	4,147	274	7.02	4,597	157	3.41
<i>Diospyros lotus</i> .....	4,399	81	1.81	5,256	68	1.29
<i>Diospyros virginiana</i> ..	1,253	44	3.34	1,716	36	2.09

Continued shedding of blossoms, immature and nearly mature fruits is the normal behavior of most Kaki persimmon varieties. The variety Hachiya is among those which exhibit this tendency. The fact that a considerable part of the shedding is of rather large fruits which are conspicuous because of their size is often of concern to the commercial grower or individual tree owner. A satisfactory yield may be obtained, although as much as 96 per cent of the total blossoms are shed as flowers or immature fruits from Hachiya on *Diospyros kaki* rootstock. A less satisfactory yield often results when Hachiya is grown on *D. lotus* rootstock.

Although a rather high percentage of flowers mature as fruits on the Hachiya on *Diospyros virginiana*, the crop is quite unsatisfactory, because of the sparse bloom.

The influence of rootstock on number of blossoms produced and the percentage which mature as fruit is quite evident. The ratio of total crops of Hachiya on *Diospyros kaki* to Hachiya on *D. lotus* for the two years 1945 and 1946 is 3.38 and 2.32 to 1 respectively. Thus more flowers were formed on the Hachiya-lotus combination but fewer fruits were matured.

The conclusions suggested by the data are: (a), a satisfactory yield in the Hachiya persimmon is obtained if 4 or 5 per cent of the flowers mature as fruits; and (b), the relatively small yields obtained from Hachiya on *Diospyros lotus* rootstock are not the result of fewer flowers produced, but of a smaller percentage of flowers which mature as fruits.

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## Relation of Growth to Fruiting in Citrus<sup>1</sup>

By G. S. RANDHAWA, and H. S. DINSA, *University of the Punjab, India*

THE ultimate objective of a commercial fruit grower is to obtain regular crops from his trees throughout their productive life. To attain this end, it is necessary for him to understand the relation of different growth characters as influenced by cultural practices, and their effect on fruit-bud formation.

Like most of the tropical and sub-tropical fruits, growth in citrus trees is cyclic, that is, successive periods of growth alternate with complete quiescence. Such periodic growths are termed "flushes". The number of flushes in a tree depends upon many factors, such as variety, climatic and weather conditions, cultural practices, amount of crop borne by such trees, their age, and so on. The citrus trees under Punjab conditions initiate growth in March which continues in the form of flushes till it finally ceases about December. During this period they produce from two to five flushes depending upon the factors mentioned above.

Numerous workers with deciduous trees and mangoes found a definite relationship between certain growth characters and fruit-bud formation. Their work, however, bears little relation to citrus. Therefore, this problem was undertaken in an important commercial variety of sweet orange known as Valencia Late.

### MATERIALS AND METHODS

Two sets of trees, (mature trees and young trees), were selected for these studies. The type of material and layout is given separately below.

*Mature Trees:*—Six mature Valencia Late trees, of uniform origin and age, were selected in the experimental orchards of the Punjab Agricultural College and Research Institute, Lyallpur, India. These plants were secured from South Africa and planted in the orchard in September, 1931, for varietal trials. Since 1935 they have borne fruit under apparently uniform conditions of soil and orchard management.

Shoots were selected on these trees for two purposes: (a) To study the behaviour of shoots carrying fruit to maturity in both the current and following seasons. Two hundred non-bearing (vegetative) and one hundred fruit bearing shoots were selected at random and labelled on each of the six experimental trees in October, 1943. Half the shoots were terminals and half, laterals. (b) To study the extension growth, leaf area, internodal length, number of laterals and so on, and their relation to fruiting. Shoots were selected at the initiation of each growth flush during the growing season of 1944. The mature trees

<sup>1</sup>A part of thesis presented to Punjab University for the degree of Master of Science in Agriculture.

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produced two flushes in the entire season. The total number of shoots studied in this case were 192.

*Young Trees*.—Six apparently uniform young trees of Valencia Late variety, just coming into bearing, were selected in the experimental orchards of the Punjab Agricultural College, Lyallpur, India. These plants had been budded *in situ* in 1940–41 on rough lemon rootstock, and were growing under uniform conditions of soil and orchard management.

Shoots were selected for a single purpose, to study the extension growth, leaf area, internodal length, and so on, and their relation to fruiting. These plants produced four growth flushes. A total of 288 shoots from these four flushes were studied. Half of these shoots were terminals and half, laterals.

The following methods were employed for recording the data.

*Extension Growth*.—The shoots were measured with a meter rod from the previous years leaf scar. Subsequent measurements were recorded at fortnightly intervals. These measurements continued until growth finally ceased.

*Leaf Area*.—The leaves of each shoot were measured without detaching them from the branch with the help of an *integrator* as described by Vyvyan and Evans (3). The measurements were taken at fortnightly intervals until leaf growth finally ceased.

*Flowering and Fruiting Records*.—The shoots selected for study of extension growth and leaf area during the growing season of 1944 were kept under observation to determine the number of blossoms borne, fruit set, and number of fruits dropped in the following season.

## RESULTS

Since all the flushes of the two sets of trees behaved alike, the March flush of both sets is taken as the representative one. The extension growth, leaf area, and their correlation with fruiting is shown graphically in Figs. 1 and 2.

The terminal and lateral shoots of all the flushes of two sets were arranged in these four classes:

- a. Non-flowering (weakly vegetative).
- b. Bearing 1 to 10 flowers.
- c. Bearing over 10 flowers.
- d. Non-flowering (highly vegetative).

Flowering proved to be correlated with extension growth, Fig. 1. Also, the terminal shoots produced more growth than did the laterals. For example, the terminal shoots of the March flush of mature trees, of the four classes showed 6.9, 10.5, 16.5, and 11.6 centimeters of extension growth respectively, as compared with 5.4, 7.8, 15.1, and 10.8 centimeters, respectively, for the lateral shoots. In young trees, the figures for the four classes of terminal shoots were 9.1, 20.5, 25.2, and 26.5 centimeters of extension growth, respectively, whereas in the lateral shoots it was 8.9, 12.1, 22.8, and 14.4 centimeters.

The curve of extension growth and leaf area of shoots in class a was the lowest, followed in order by classes b, d, and c, except in terminal

shoots of young trees where class d had more extension growth and leaf area than class c, Figs. 1 and 2. Therefore, among the flowering shoots the longer shoots bore more flowers than did the shorter ones.

The June flush showed the highest percentage of flowering shoots, followed by the March, July, and September flushes in this order. It

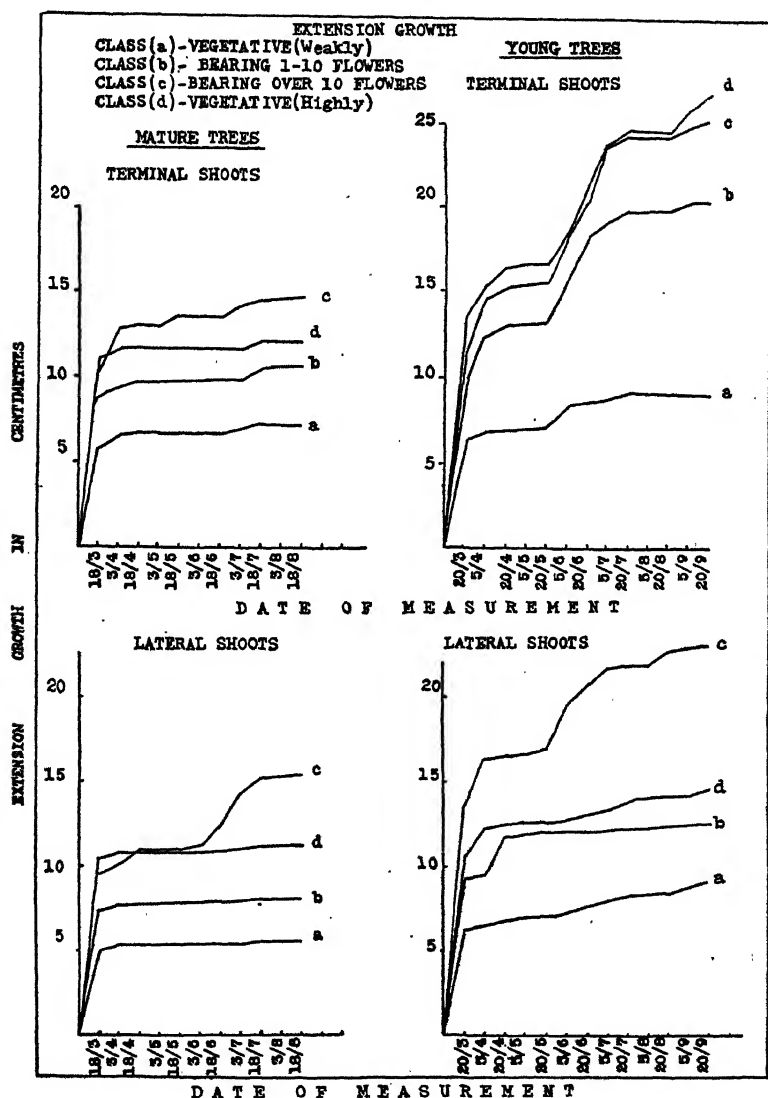


FIG. 1. Cumulative extension growth of March flush in relation to number of blossoms formed.

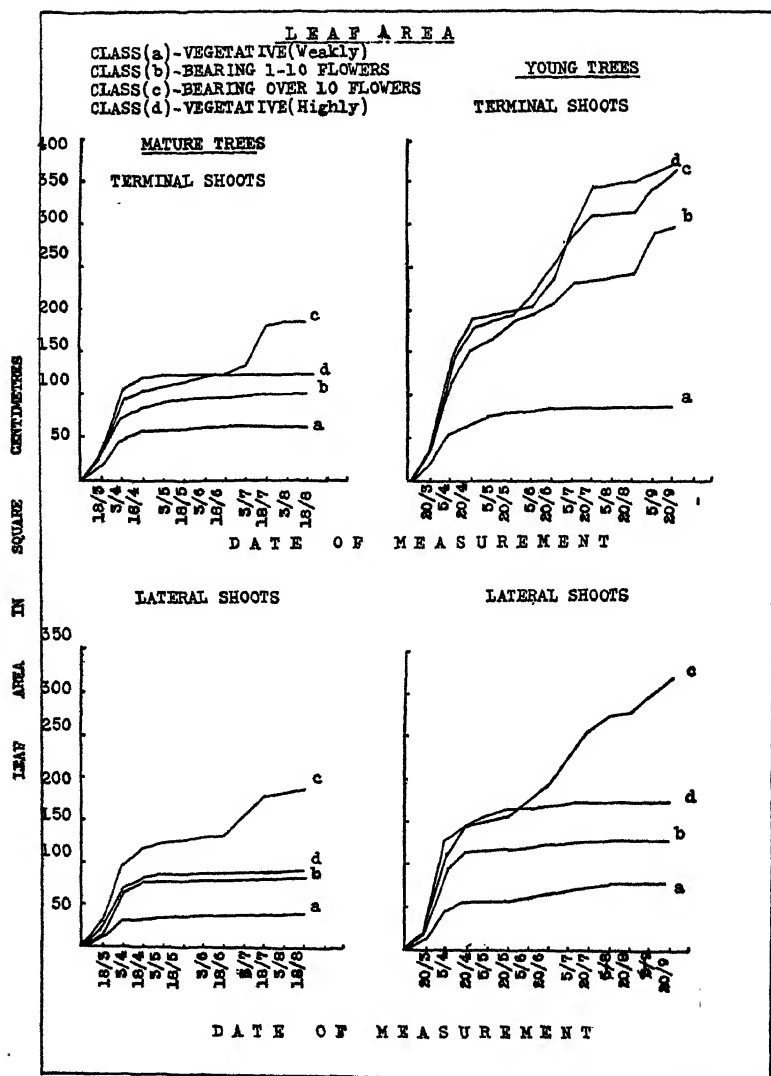


FIG. 2. Leaf area of March flush shoots in relation to the number of blossoms formed.

was concluded, therefore, that the earlier flushes were of higher productive capacity than the late ones, in both sets of trees, Tables I and II.

*Fruiting Records:*—No relationship was found between the crop that remained on the shoots after the *June drop* and the number of blossoms borne by each shoot. In the mature trees, however, 42.0 per cent of the total blossoms set fruit and only 3.3 per cent remained

TABLE I—BEHAVIOUR OF DIFFERENT GROWTH FLUSHES OF MATURE TREES\*

Material	Percentage of Non-Flowering Shoots		Percentage of Shoots Bearing 1 to 10 Flowers	Percentage of Shoots Bearing Above 10 Flowers
	Highly Vegetative	Weakly Vegetative		
March Flush				
Terminal...	14.5	12.5	41.7	31.3
Lateral.....	18.9	14.5	39.6	27.0
Average....	16.7	13.5	40.7	29.1
July Flush				
Terminal...	23.0	23.0	37.5	16.5
Lateral.....	13.6	29.1	43.8	13.5
Average....	18.3	26.1	40.6	15.0

\*The March flush formed higher percentage of flowering shoots than did the July flush.

TABLE II—BEHAVIOUR OF DIFFERENT GROWTH FLUSHES OF YOUNG TREES

Material	Percentage of Non-Flowering Shoots		Percentage of Shoots Bearing 1 to 10 Flowers	Percentage of Shoots Bearing Above 10 Flowers
	Highly Vegetative	Weakly Vegetative		
March Flush				
Terminal...	12.4	4.2	14.6	68.8
Lateral....	10.4	8.3	27.1	54.2
Average....	11.4	6.3	20.9	61.5
June Flush				
Terminal...	4.2	6.3	27.0	62.5
Lateral....	4.4	16.5	27.0	52.1
Average....	4.3	11.4	27.0	57.3
July Flush				
Terminal...	—	16.7	25.0	58.3
Lateral....	8.4	20.8	29.2	41.6
Average....	4.2	18.7	27.1	50.0
September Flush				
Terminal...	20.8	8.3	29.2	41.7
Lateral....	25.0	8.3	29.2	37.5
Average....	22.9	8.3	29.2	39.6

on the tree after June. In the young trees, 16.8 per cent of the blossoms set fruit and only 1.1 per cent remained on the tree after June.

#### BEHAVIOUR OF SHOOTS CARRYING FRUIT TO MATURITY

*Fruiting Branches:*—Of the shoots which bore fruit in 1943, 11.1 per cent flowered, 70.7 per cent remained vegetative, 18.2 per cent dried and finally, 5.6 per cent matured fruits in spring 1944. But, the same shoots in 1945 season showed 43.4 per cent flowering, 17.4 per cent remaining vegetative, 39.2 per cent dried and finally, 25.8 per cent retained fruit after the June drop, Table III.

*Non-fruited Branches:*—Of all the shoots that remained flowering in 1943, 36.2 per cent remained vegetative, 61.6 per cent flowered, 2.2 per cent dried, and 46 per cent retained fruit after the *June drop* in 1944. Of the same branches 66.1 per cent remained vegetative, 26.7 per cent flowered, 7.2 per cent dried, and 12.4 per cent retained fruit after the *June drop* in 1945, Table IV.

TABLE III—BEHAVIOUR OF FRUITING BRANCHES IN SUBSEQUENT YEARS

Material	No.	1944				1945			
		Vegetative	Flowering	Fruiting	Dead	Vegetative	Flowering	Fruiting	Dead
Terminal....	350	252	38	17	60	68	166	97	116
Lateral.....	350	243	40	22	67	54	138	84	158
Total shoots..	700	495	78	39	127	122	304	181	274
Percentage..		70.7	11.1	5.6	18.2	17.4	43.4	25.8	39.2

TABLE IV—BEHAVIOUR OF NON-FRUITING BRANCHES IN SUBSEQUENT YEARS

Material	No.	1944				1945			
		Vegetative	Flowering	Fruiting	Dead	Vegetative	Flowering	Fruiting	Dead
Terminal....	700	241	442	324	17	479	186	90	34
Lateral.....	700	266	420	319	14	447	188	84	55
Total shoots..	1400	507	862	643	31	926	374	174	89
Percentage..		36.2	61.6	46.0	2.2	66.1	26.7	12.4	7.2

It was concluded from these studies that the shoots of Valencia Late variety have a very strong tendency to *alternate bearing*, that is, a high proportion of shoots which bear one year remain barren in the next year.

#### MEAN SHOOT LENGTH, MEAN NUMBER OF NODES, AND MEAN LEAF AREA PER SHOOT

The mean length, mean number of nodes or leaves, and mean leaf area per shoot was markedly greater in the flowering shoots than in the non-flowering ones. In the young trees there was, however, one exception, *viz.*, in the case of the June flush the leaf area per shoot was slightly more in non-flowering than in flowering shoots. It was also observed that mean length, mean number of nodes and the leaf area per shoot was much greater in young than in mature trees, Table V.

#### MEAN LEAF AREA PER UNIT SHOOT LENGTH, LEAF SIZE, AND INTERNODAL LENGTH

In the March flush of mature trees the leaf area per centimeter shoot length was more in flowering than in non-flowering shoots, whereas in the July flush it was equal in both the flowering and non-flowering shoots. Leaf size was greater in the flowering shoots than in the non-flowering shoots. Internodal length did not show any relationship with flowering.

In young trees, leaf area per centimeter of shoot length was more in flowering shoots of March and September flushes than in non-flowering shoots, but in the June and July flushes it was quite the reverse. Leaf size was greater in the non-flowering than in the flowering shoots, except in the September flush where the leaves of the

TABLE V—MEAN SHOOT LENGTH, MEAN NUMBER OF NODES, AND MEAN LEAF AREA PER SHOOT IN DIFFERENT GROWTH FLUSHES (1944)

Season	Flowering or Non-flowering	Mean Length (Cm)	Mean No. of Nodes	Leaf Area Per Shoot (Sq Cm)
<i>A. Mature Trees</i>				
March flush.....	Non-flowering	8.7	4.5	75.9
	Flowering	12.5	7.3	136.5
July flush.....	Non-flowering	8.2	6.1	117.5
	Flowering	9.7	6.7	140.3
<i>B. Young Trees</i>				
March flush.....	Non-flowering	14.7	8.4	178.3
	Flowering	20.2	17.0	247.8
June flush.....	Non-flowering	10.5	6.9	189.6
	Flowering	10.6	8.7	178.5
July flush.....	Non-flowering	6.8	4.4	138.7
	Flowering	10.6	8.1	171.2
September flush.....	Non-flowering	9.7	6.5	109.8
	Flowering	13.7	8.2	184.9

flowering shoots were larger than in the non-flowering shoots. The internodal length in the non-flowering shoots was more than in the flowering shoots, except in the September flush.

Comparison of these two sets of trees revealed that young trees developed more leaf area per centimeter shoot length and larger leaves than mature trees. No difference was found in internodal length, Table VI.

From these studies it was concluded that mean leaf area per centimeter shoot length, leaf size, and internodal length had no correlation with fruiting.

*Number of Laterals:*—The March flush of each set produced the most laterals. In young trees, the July and September flushes did not

TABLE VI—MEAN LEAF AREA PER UNIT LENGTH, LEAF SIZE, AND INTERNODAL LENGTH IN DIFFERENT GROWTH FLUSHES (1944)

Season	Flowering or Non-flowering	Leaf Area Per Cm Shoot Length	Leaf Size (Sq Cm)	Internodal Length (Cm)
<i>A. Mature Trees</i>				
March flush.....	Non-flowering	8.7	8.7	1.9
	Flowering	10.9	10.9	1.7
July flush.....	Non-flowering	14.4	14.3	1.3
	Flowering	14.4	14.5	1.4
<i>B. Young Trees</i>				
March flush.....	Non-flowering	12.1	21.2	1.8
	Flowering	13.7	14.7	1.2
June flush.....	Non-flowering	18.1	27.0	1.5
	Flowering	16.8	20.5	1.2
July flush.....	Non-flowering	20.4	31.5	1.5
	Flowering	16.2	21.1	1.3
September flush.....	Non-flowering	11.3	16.9	1.5
	Flowering	13.5	22.5	1.7

produce a single lateral. On the whole, young trees produced many more laterals than did mature trees. In the March flush of the two sets of trees, terminal shoots produced many more laterals than did the lateral shoots. In other flushes the number of laterals produced was more or less the same.

#### GROWTH RATES OF VALENCIA ORANGES

The measurements of size of Valencia Oranges were started in April, 1944, and continued until harvest. The average diameter per fruit on April 18, was 0.6 centimeters and on October 3 it had increased to 5.9 centimeters. After this date, the growth was slow and finally ceased on January 3, 1945, when maximum size had been attained, 6.4 centimeters (Fig. 3).

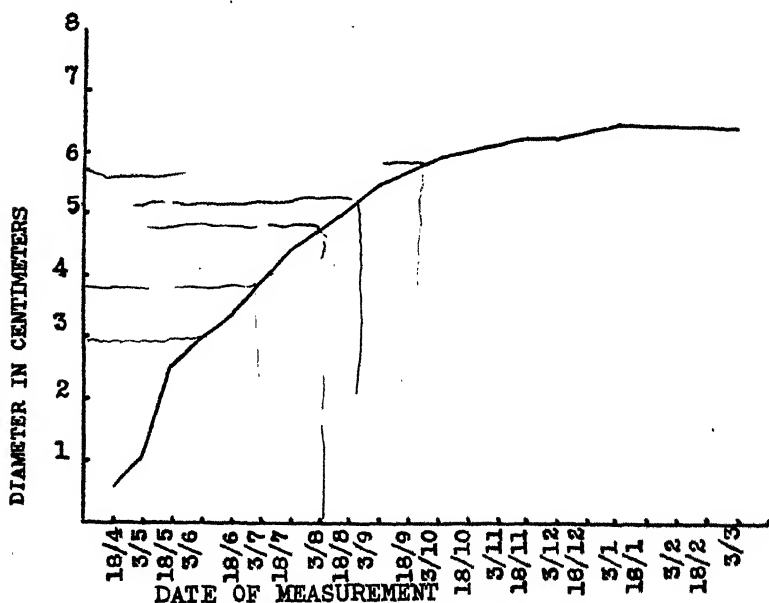


FIG. 3. Growth rates of Valencia Late oranges.

#### DISCUSSION

A definite correlation existed between the elongation growth of shoots and fruiting in citrus. Among the flowering shoots, the longer ones bore more blossoms than did the weak or medium shoots. This was true in both mature and young trees. Longer shoots, no doubt, bore more blossoms, but shoots of medium length were found more productive. In the March flush of the mature trees, out of a total of 69.8 per cent flowering shoots, 40.7 per cent were of medium elongation. In the July flush, out of a total of 55.6 per cent flowering shoots, 40.6 per cent were of medium elongation. It did not, however, hold

true in young trees. The present studies did not indicate any relation between extension growth and fruit setting. Many workers, with deciduous fruits, found that variation in leaf area had a profound effect upon the fruit formation. In present studies the shoots with more leaf area produced more blossoms than did shoots with less leaf area. The rate of growth and the time at which growth ceased showed no correlation with blossoming or setting of fruit. Singh (2), working with Mandarin orange, agreed with the above findings.

The earlier flushes were more fruitful than those which were initiated late in the growing season. For example, in the March flush of mature trees, 69.8 per cent shoots bore fruit and 30.2 per cent remained unfruitful, whereas in the July flush only 55.6 per cent bore fruit and 44.4 per cent remained vegetative. In young trees, March and June flushes had a higher percentage of fruiting shoots than the July and September flushes.

Study of the shoots carrying fruit to maturity indicated that individual shoots of Valencia Late had a strong tendency to *alternate bearing*. Hodgson (1), Waynick (5), West and Barnard (7), and West and Allen (6) have studied the alternate bearing habit of this variety. They held that the heavy crops of one year had a depressing effect on the amount of cropping in the succeeding year. This effect increased with the length of time the crop remained on the tree, because Valencia is a late variety and bears, for some time, the load of two crops, that is, the new crop of the succeeding year and the old maturing crop. They recommended early harvesting and thinning of fruit to eliminate this *alternate bearing* habit.

The size of Valencia oranges increase rapidly from April to October. It is evident, therefore, that unless the fruits attain normal size by October, a normal size crop cannot be expected at the harvest time. Growers should control factors which affect the size of the fruit during this period. Waynick (4) pointed out that soil moisture, nitrogen content, and sunlight are the limiting factors in the growth of Valencia oranges. Of these three factors, moisture, its adequacy or inadequacy, was of greatest significance. It is imperative for the growers, therefore, to take the utmost care in irrigation during this period. Since the earlier flushes were more productive, all the cultural operations aimed at adjusting the fruiting must be performed before growth starts in spring.

#### SUMMARY

- Flowering bore a definite relation to extension growth. Among the flowering shoots the longer ones bore more blossoms than did the medium or short shoots. However, shoots of medium elongation were more productive than the longer or shorter shoots.

- Correlation between leaf area and blossoming was highly suggestive.

- Young trees grew more vigorously than mature trees. Terminal shoots produced more extension growth and leaf area than the lateral shoots.

Early growth flushes were more productive than late flushes.



There existed no relation between growth and fruit setting.

The individual shoots of Valencia Late variety had a strong tendency to, *alternate bearing*.

The mean length, mean number of nodes, and mean leaf area per shoot were greater in flowering than in non-flowering shoots.

Leaf area per centimeter shoot length and internodal length bore no relation to flowering.

In mature trees flowering shoots had bigger leaves than non-flowering shoots; in young trees the case was quite the reverse.

The March flush produced more laterals than other flushes. Terminal shoots produced more laterals than lateral shoots. On the whole, young trees produced markedly more laterals than did mature trees.

The growth in Valencia oranges took place from April to January. There was no further size increase after January.

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## Quality of Valencia Oranges as Affected by Aspect, Exposure, and Height On the Tree<sup>1</sup>

By GURCHARAN S. RANDHAWA and H. S. DINSA, *Ontario Agricultural College, Guelph, Ontario*

SWEET orange is grown extensively in the canal colonies of the Punjab, India, where, as in the interior valleys of Southern California, constant sunshine and high temperature are the rule. In some varieties of sweet orange the heat reduces the quality of fruit in certain sectors of the tree which are exposed to direct radiation. Therefore, the growers in such localities need to plant varieties which produce high quality fruit on all sectors of the tree.

Valencia, a late variety, produces a good income for the growers. It is also hardy and retains its ripened fruit on the tree for a long time without deterioration. It was planned, therefore, to measure the effect of aspect, exposure, and height on the fruit quality of this variety. Such studies should be of value to the grower who can utilize such information to encourage fruiting at certain sectors of his trees in order to obtain fruit of good quality.

### MATERIALS AND METHODS

Six mature sweet orange trees of Valencia Late variety of uniform age and origin were selected in the experimental orchards of the Punjab Agricultural College and Research Institute, Lyallpur, India. These plants were secured from South Africa and planted in the orchard in September, 1931. They have produced average crops under apparently uniform conditions of soil and orchard management.

Each tree was divided into four parts according to the direction, that is, northeast, northwest, southwest, and southeast. Each part was further subdivided into halves, upper half and lower half. Thus, the whole tree was divided into eight sectors. The uppermost and lowermost parts of these trees were left as checks.

The fruit was harvested in mid-March for the purpose of physico-chemical analysis. Each of the above sectors was further subdivided into four portions: A, upper half exposed; B, upper half shaded; C, lower half exposed; and D, lower half shaded. Six fruits were selected from each of the above portions and marked as A, B, C, or D. Thus  $24 \times 4$  or 96 fruits were selected from each tree. The total number of fruits analyzed from all the experimental trees was  $24 \times 4 \times 6$  or 576.

The following factors were considered in the physico-chemical analysis: weight per fruit, weight of peel, weight of juice, weight of pomace, total solids, acidity, and total solids/acid ratio. The effect of aspect,

<sup>1</sup>A part of a thesis presented to the University of the Punjab, in partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

The authors are respectively, research scholar of Government of India, and assistant fruit specialist, Punjab, India.

The authors wish to express their appreciation to B. S. Bajwa, Fruit Specialist, Punjab, for his guidance; to Dr. J. S. Shoemaker, Department of Horticulture, Ontario Agricultural College, Guelph, Ontario, and to Dr. W. H. Upshall, Horticultural Experiment Station, Vineland, Ontario, Canada, for suggestions in the preparation of this manuscript.

exposure, and height on these qualities of the fruit was reported under these headings. Under results all data is presented in summarized form.

### RESULTS

#### 1. *Weight per fruit:—*

##### *Aspect*

Southwest .....	212.3 grams
Southeast .....	204.2 grams
Northeast .....	198.5 grams
Northwest .....	192.7 grams
Critical difference is 8.32	

Fruit from the southwest side was heavier than fruit from the northwest side. The fruit from the southeast side was also heavier than fruit from the northwest side but not significantly so. The difference in weight per fruit between northeast and northwest, and southeast and southwest is insignificant.

##### *Exposure*

	<i>Exposed</i>	<i>Shaded</i>
Southwest .....	177.4 grams	247.3 grams
Southeast .....	178.1 grams	230.4 grams
Northeast .....	164.8 grams	232.3 grams
Northwest .....	157.9 grams	227.6 grams
Critical difference is 5.87		

The shaded fruits were considerably heavier than the exposed ones.

##### *Height*

The effect of height on weight per fruit was found to be statistically insignificant.

#### 2. *Percentage Juice:—*

##### *Aspect*

	<i>Juice</i>
Southwest .....	44.1 per cent
Southeast .....	47.3 per cent
Northeast .....	42.8 per cent
Northwest .....	45.1 per cent
Critical difference is 3.14	

Fruit on the southeast side was more juicy than fruit on the northeast side. There is insignificant difference in juice content between the fruits of southeast and southwest, and northeast and northwest sides.

##### *Exposure*

The effect of exposure on juice percentage was insignificant.

##### *Height*

	<i>Juice</i>
Upper half .....	43.5 per cent
Lower half .....	46.3 per cent
Difference .....	2.8 per cent
Critical difference is 1.37	

Fruit of the lower half of the tree contained more juice than did fruit of the upper half.

3. *Percentage Pomace:—*

*Aspect and Exposure*

The effect of aspect and exposure on pomace percentage was statistically insignificant.

*Height*

	<i>Pomace</i>
Upper half .....	25.8 per cent
Lower half .....	<u>24.0</u> per cent
Difference .....	1.8 per cent
Critical difference is 1.71	

Fruit of the upper half contained more pomace than fruit of the lower half.

4. *Percentage Peel:—*

*Aspect and Height*

The effect of aspect and height on percentage peel was insignificant.

*Exposure*

	<i>Peel</i>
Exposed .....	29.8 per cent
Shaded .....	<u>31.1</u> per cent
Difference .....	1.3 per cent
Critical difference is 1.27	

Shaded fruits had a higher percentage of peel.

5. *Total Solids and Acidity:—*

The effect of aspect, exposure, and height on percentage total solids and on acidity was statistically insignificant.

6. *Total Solids/Acid Ratio:—*

*Aspect*

The effect of aspect on total solids/acid ratio was insignificant.

*Exposure*

Exposed .....	12.0
Shaded .....	<u>10.8</u>
Difference .....	1.2
Critical difference is .84	

Exposed fruits had a higher total solids/acid ratio than did the shaded ones.

*Height*

Upper half .....	11.9
Lower half .....	<u>11.0</u>
Difference .....	.9
Critical difference is .84	

Juice from fruit of the upper half had a significantly higher total solids/acid ratio than the juice from fruit of the lower half.

The data given above in summarized form reveal that exposed fruits on the tree were thin-skinned with a higher total solids/acid ratio. Shaded fruits on the other hand were heavier than the exposed ones. The fruit of the upper half was heavier and with a higher total solids/acid ratio than fruit of the lower half, whereas fruit of the lower half ranked higher in percentage of juice.

The investigation also indicates that heat does not reduce the quality of Valencia oranges but rather improves it in many respects. Valencia is a late variety which, besides possessing the good qualities mentioned before, produces high quality fruit all over the tree under hot climatic conditions. In all new plantations that are coming into existence in the hot regions this variety should, therefore, find a prominent place.

# Time of Blossom-Bud Differentiation in Citrus<sup>1</sup>

By GURCHARAN S. RANDHAWA, and H. S. DINSA,  
*University of the Punjab, India*

IN almost all the deciduous fruits grown in the temperate zones, the time of blossom-bud differentiation varies considerably depending upon such factors as the species, the variety, climatic and weather conditions, cultural practices, rootstocks, and age of tree. Although this subject has been widely studied with deciduous fruits, the findings bear little relation to evergreen fruits, especially citrus. A limited study previously has been made of the time of blossom-bud differentiation in citrus and it is summarized in Table I.

TABLE I—BRIEF SUMMARY OF WORK ON CITRUS IN DIFFERENT COUNTRIES

Fruits	Locality	Differentiation First Noted	Research Worker
<i>Sweet Orange</i>			
Pineapple.....	Florida, U. S. A.	Jan 29	Abbott (1)
Pineapple.....	Florida, U. S. A.	Jan 18	Abbott (1)
Pineapple.....	Florida, U. S. A.	Jan 12	Abbott (1)
Valencia.....	Griffith, N.S.W. Australia	Early spring	West and Barnard (7)
Washington Navel	Griffith, N.S.W. Australia	Early spring	West and Barnard (7)
<i>Mandarin Orange</i>			
'Nagpuri Sangtara'	Punjab, India	Spring with advent of growth	Singh (5)
Owari Satsuma....	Florida, U. S. A.	Jan 26	Abbott (1)
<i>Kumquat</i>			
Nagami.....	Florida, U. S. A.	May 20	Abbott (1)
Citrus species.....	Tanaka, Japan		Hiroto (4)

An essential factor in commercial orcharding is to obtain maximum gross returns with minimum expenditure and this is only possible if regular and adequate yields are obtained annually. And so, with citrus fruits all cultural operations such as pruning, fertilizing (manuring), irrigation, and root pruning, which control blossom-bud differentiation must be performed at the proper time, that is, before the buds begin to differentiate. Determination of the time of blossom-bud differentiation is therefore a problem of great importance. In view of the above facts, this problem was studied in two important species of citrus, viz., sweet orange (*Citrus sinensis*, Osbeck) and sweet lime (*Citrus aurantifolia*, Swingle).

## MATERIALS AND METHODS

Three mature sweet orange trees of Valencia Late variety of uniform origin and age were selected in the experimental orchards of the Punjab Agricultural College and Research Institute, Lyallpur, India.

<sup>1</sup>This work was done at the University of Punjab, India, in partial fulfilment of the requirements for the degree of Master of Science in Agriculture. The authors wish to express their appreciation to B. S. Bajwa, Fruit Specialist, Punjab, for his guidance; and to Dr. J. S. Shoemaker, Department of Horticulture, O.A.C., Guelph, and to Dr. W. H. Upshall, Horticultural Experiment Station, Vineland, Ontario, for suggestions in the preparation of this manuscript.

These plants were secured from South Africa and planted in the orchard in September, 1931, for varietal trials. Since 1935 they have borne fruit under apparently uniform conditions of soil and orchard management.

Three apparently uniform trees of sweet lime were selected. These plants were raised *in situ* from cuttings in March 1928 on a piece of sandy loam soil in the experimental orchards of the Punjab Agricultural College, Lyallpur, India.

✓ In citrus fruits, unlike the case in deciduous trees, it is not possible to distinguish between a fruit bud and a vegetative bud, either by the position of the bud on the tree or by its size or shape. Therefore, six shoots were selected at random on all three trees of each species under study and buds were obtained from them in each sampling. From every sample shoot one terminal and two lateral buds immediately below the terminal bud were obtained and kept separately in formalin-acetic-alcohol (fixative) for subsequent histological study. Collections were made from the spring, summer, and fall flushes of growth on the two species. Sampling was started on September 15, 1944, samples being collected at an interval of 1 month until December and thereafter fortnightly. The last sample was obtained on March 1 when growth had started. A total of about 800 buds of the two species were put to the microtome. At the time of study the buds were removed from the fixative and thoroughly washed in running water for 24 hours to ensure complete removal of the fixative. The washed material was passed through different concentrations of alcohol to ensure dehydration and hardening of the material. It was then cleared in xylol and embedded in paraffin. The Cambridge rocking microtome was employed for sectioning and sections were cut at 10 to 17 microns. Haup's and Mayer's adhesives were used for holding the sections on the slides. Safranin and Light Green were used in staining.

## RESULTS

The flattening of the apical meristem with two lateral protuberances, one on either side of it, was established as the criterion of blossom-bud differentiation in these investigations.

The data given in the tables reveal that in both sweet orange and sweet lime no evidence of differentiation was found before January 1, but by March 1 most of the buds had differentiated.

The blossom-bud differentiation began from January 31 onwards. ✓ But, soon after this date the weather cooled down considerably due to heavy frost which arrested the growth as well as the differentiation for some time. After the weather warmed up differentiation was observed in buds collected February 15. Another heavy frost on February 17 again arrested the blossom-bud differentiation. The weather warmed up after February 24 and the active differentiation then started and by March 1 most of the buds had differentiated.

It was also observed that more buds in early flushes were differentiated than in the late ones. For instance, in the spring (March) flush of the sweet orange 67 per cent terminal and 42 per cent lateral buds

TABLE II—SWEET ORANGE

Date of Sampling	No. of Buds Examined	Differ-entiated	Pre-differ-entiated	Undiffer-entiated
<i>March Flush Terminal Buds</i>				
Dec 15, 1944.....	6	—	—	6
Dec 31, 1944.....	6	—	—	6
Jan 15, 1945.....	6	—	—	6
Jan 31, 1945.....	6	—	2	4
Feb 15, 1945.....	6	3	2	1
Mar 1, 1945.....	6	4	—	2
<i>March Flush Lateral Buds</i>				
Dec 31, 1944.....	12	—	—	12
Jan 15, 1945.....	12	—	—	12
Jan 31, 1945.....	8	—	1	7
Feb 15, 1945.....	12	1	2	9
Mar 1, 1945.....	12	5	4	3
<i>July Flush Terminal Buds</i>				
Dec 31, 1944.....	6	—	—	6
Jan 15, 1945.....	6	—	—	6
Jan 31, 1945.....	6	—	—	6
Feb 15, 1945.....	6	—	3	3
Mar 1, 1945.....	6	3	2	1
<i>July Flush Lateral Buds</i>				
Dec 15, 1944.....	12	—	—	12
Dec 31, 1944.....	12	—	—	12
Jan 15, 1945.....	12	—	—	12
Jan 31, 1945.....	12	—	2	10
Feb 15, 1945.....	12	1	4	7
Mar 1, 1945.....	12	4	3	5

had differentiated by March 1, whereas in the summer (July) flush only 55 per cent terminal and 33 per cent lateral buds had differentiated by that date. Also, the terminal buds had differentiated to a greater degree than the lateral buds. In the case of sweet lime, however, no such distinction was observed.

## DISCUSSION

The flattening of the apical meristem with two lateral protuberances, one on either side of it, was established as the criterion of blossom-bud differentiation. These projections are inwardly curved and represent the sepals of the flower. Waldo (6) found that definite blossom-bud differentiation in strawberry was considered to have begun when the growing point had become broad and somewhat flattened at the top. Goff (3) working with the same fruit regarded the broadening and irregular outline of the growing point as an indication of an early stage of flower development. Abbott (1), in his investigations on some citrus species, observed that "the blossom-bud differentiation was considered to have begun when longitudinal sections of the buds showed a broadening of the growing point with concurrently developed lobes." The criterion established in the present investigation, therefore, agrees with the findings in the literature of the above authors.

Ball (2), working on time of differentiation of plum, pointed out that "a rigid date cannot be given as the time for the change of the



TABLE III—SWEET LIME

Date of Sampling	No. of Buds Examined	Differen- tiated	Pre-differ- entiated	Undiffer- entiated
<i>March Flush Terminal Buds</i>				
Sep 15, 1944.....	6	—	—	6
Oct 15, 1944.....	6	—	—	6
Nov 15, 1944.....	6	—	—	6
Dec 15, 1944.....	6	—	—	6
Jan 15, 1945.....	6	—	—	6
Jan 31, 1945.....	6	—	2	4
Feb 15, 1945.....	6	—	3	3
Mar 1, 1945.....	6	4	2	—
<i>March Flush Lateral Buds</i>				
Sep 15, 1944.....	12	—	—	12
Oct 15, 1944.....	12	—	—	12
Nov 15, 1944.....	12	—	—	12
Dec 15, 1944.....	12	—	—	12
Dec 31, 1944.....	12	—	—	12
Jan 15, 1945.....	12	—	—	12
Jan 31, 1945.....	12	—	4	8
Feb 15, 1945.....	12	2	4	6
Mar 1, 1945.....	12	8	2	2
<i>July Flush Terminal Buds</i>				
Sep 15, 1944.....	6	—	—	6
Oct 15, 1944.....	6	—	—	6
Nov 15, 1944.....	6	—	—	6
Dec 15, 1944.....	6	—	—	6
Dec 31, 1944.....	6	—	—	6
Jan 15, 1945.....	6	—	—	6
Jan 31, 1945.....	6	—	2	4
Feb 15, 1945.....	6	1	5	—
Mar 1, 1945.....	6	4	1	1
<i>July Flush Lateral Buds</i>				
Sep 15, 1944.....	12	—	—	12
Oct 15, 1944.....	12	—	—	12
Nov 15, 1944.....	12	—	—	12
Dec 15, 1944.....	12	—	—	12
Dec 31, 1944.....	12	—	—	12
Jan 15, 1945.....	12	—	—	12
Jan 31, 1945.....	12	—	2	10
Feb 15, 1945.....	12	—	4	8
Mar 1, 1945.....	12	6	3	3
<i>September Flush Terminal Buds</i>				
Sep 15, 1944.....	6	—	—	6
Oct 15, 1944.....	6	—	—	6
Nov 15, 1944.....	6	—	—	6
Dec 15, 1944.....	6	—	—	6
Dec 31, 1944.....	6	—	—	6
Jan 15, 1945.....	6	—	—	6
Jan 31, 1945.....	6	—	1	5
Feb 15, 1945.....	6	2	2	2
Mar 1, 1945.....	6	4	2	—
<i>September Flush Lateral Buds</i>				
Oct 15, 1944.....	12	—	—	12
Nov 15, 1944.....	12	—	—	12
Dec 15, 1944.....	12	—	—	12
Dec 31, 1944.....	12	—	—	12
Jan 15, 1945.....	12	—	—	12
Jan 31, 1945.....	12	—	2	10
Feb 15, 1945.....	12	1	4	7
Mar 1, 1945.....	12	9	3	—

vegetative bud into the fruit bud. The factors causing the variation are variety, season, position of the bud on the tree, and cultural treatment. This is also in line with the findings of the various investigators who have studied different varieties of citrus species.

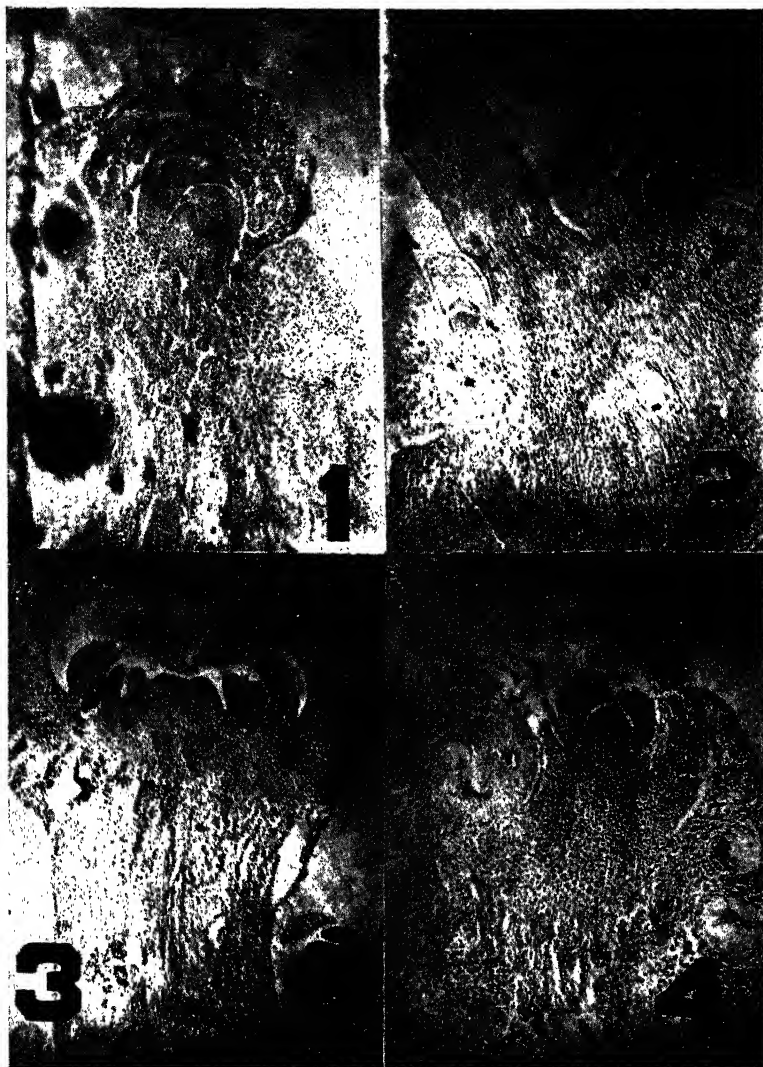


FIG. 1. 1, Undifferentiated sweet orange bud collected January 15. Growing point is long, conical and tightly enclosed by scales. 2, Pre-differentiated sweet orange bud collected February 15. Growing point is broader than in undifferentiated bud, and is less tightly enclosed. The scales, in turn, have become broader. 3, Sweet orange bud collected March 1 showing early development of a complete flower. The sepals and petals are well developed with early indication of stamen formation. The pistil primordia is also evident, as are two lateral buds in the axil of the bud. 4, Pre-differentiated bud of sweet lime collected February 15.

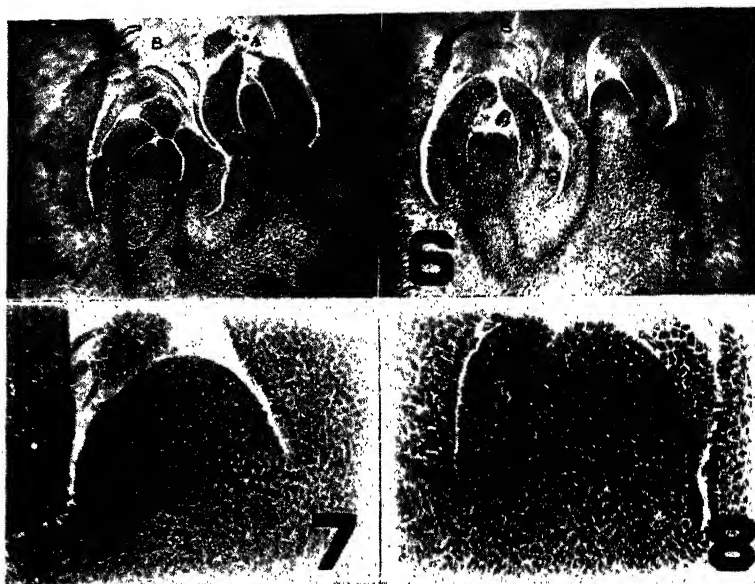


FIG. 2. 5, *Bud A* shows pre-differentiation stage and *bud B* shows advanced stage of pre-differentiation. The growing point in *bud B* is broader than that in *bud A*. 6, Sweet lime bud collected March 1—*Bud A* shows early stage of differentiation and *bud B* presents complete differentiation. The growing point in *bud B* is markedly large as compared with *bud A*. The two protuberances on the side of flattened apical meristem are evident. 7, Shows *bud A* of 6, under high power. 8, Shows *bud B* of 6 under high power.

The present investigations show that blossom-bud differentiation in both sweet orange and sweet lime takes place in spring with the advent of growth. The period of differentiation may extend over a period of time depending upon the weather conditions. In these studies the period extended over one month because of the interference of frost during that period. Abbott (1), who studied the Pineapple variety of sweet orange, found slight difference in the time of differentiation from year to year. Singh (5) holds that, in the mandarin orange, the interval between differentiation or initiation of growth and formation of flowers hardly exceeds a week's time.

In this study, in both sweet orange and sweet lime, blossom-bud differentiation has been found to begin as soon as growth commences. The interval between growth initiation and differentiation is therefore not as long as in deciduous fruits. Since the period of blossom-bud differentiation is short and because growth and differentiation go hand in hand, all cultural operations aimed at adjusting the amount of crop in these citrus fruits must be performed well before growth starts in spring.

### SUMMARY

1. The flattening of the apical meristem with two lateral protuberances, one on either side of it, was established as the criterion of blossom-bud differentiation in these studies.

2. Blossom-bud differentiation in both sweet orange and sweet lime commenced in spring with advent of growth.

3. In sweet orange, more buds of the early flushes had differentiated as compared with late flushes. In sweet lime, no such distinction was observed.

4. In sweet orange, terminal buds differentiated in greater degree than lateral buds. This was not the case in sweet lime.

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## Own-Rooted and Budded Lemon Trees

By F. F. HALMA, *University of California, Los Angeles, Calif.*

IN 1926, an extensive investigation of the citrus rootstock problem was initiated by the Citrus Experiment Station, Riverside. One phase of this investigation, assigned to the writer who was then on the Riverside staff, was a comparative study of own-rooted (trees propagated by stem cuttings) and budded trees. Accordingly, a method for rooting and handling cuttings was developed, and between 1931 and 1936 seven Naval orange, eleven Valencia orange, and five Eureka lemon field plots were established.

Of interest is the fact that, so far, lemon cuttings have been consistently less productive and, except for the first 4 years, less vigorous than budlings, while no consistent differences have occurred in the oranges. For this reason a report on the lemon is warranted primarily as a means of caution against extensive planting of lemon cuttings.

It has been known for a long time that the lemon can be easily propagated by cuttings. Records indicate that own-rooted lemon trees were planted in fairly large numbers in southern California probably over 80 years ago. Conger (1) in 1889 reported being so favorably impressed with a few bearing lemon trees on their own roots that he planted several thousand on his ranch (presumably in the Pasadena area). A year later on (2) reiterated his belief in the superiority of cuttings over budded trees, but some of the growers present at the meeting disagreed with him. The subject was not mentioned in subsequent reports.

In view of the fact that there are many lemon strains and that they vary greatly in vigor and productivity, it is obvious that in order to evaluate the relative merits of cuttings and budlings, progenies of the same parents be used for both. There is nothing in the records to indicate that this has been done.

### SCOPE OF THE INVESTIGATION

This report is based mainly on five plots. Four plots were planted in close proximity to one another near the Upland foothills, San Bernardino County, three of them in 1932 and one in 1933. In each plot both the cuttings and budlings, on grapefruit rootstock, are progenies of one parent, and for each plot a different parent was used. The soil is classed as Hanford rocky, sandy loam.

The fifth plot, located near Oxnard, Ventura County, was planted in 1936. The cuttings and budlings are progenies of one parent, and the rootstock is sweet orange. The soil is a Yolo fine sandy loam.

These five plantings included 334 cuttings and 337 budlings, five Eureka lemon scion strains, and grapefruit and sweet orange rootstocks. Orchard management varied according to each cooperator's practice.<sup>1</sup>

<sup>1</sup>In Upland the cooperators were Norman Lawson, William Rohrig, E. W. Henry, and S. H. Yahres, former manager of the Highland ranch, and his successor, A. J. Robinson. The Oxnard planting was made on the Utt Development Company Ranch by the late C. V. Newman, and the project is being continued by his successor, J. V. Newman. The great interest and most hearty cooperation on the part of these growers is hereby gratefully acknowledged.

## TREE HISTORY

All cuttings and budlings for the Upland plantings were grown on the Norman Lawson property in Upland with J. W. Conner, nurseryman of La Verne, in charge of the nursery. Cuttings and buds were taken from four Eureka type parent trees selected by the four co-operators. These trees, on grapefruit stock and planted about 1912, are located on the Highland ranch, Upland. They varied in growth habit and vigor, but all had a good production record and were free from diseases.

The cutting propagation method used has been published (3), hence requires only brief mention. Twigs 4 to 6 inches long, possessing 5 to 6 leaves, were taken from the mature terminal growth. The lower 2 or 3 leaves were removed which left 3 or 4 leaves. The cuttings were then placed in a sash-covered propagating frame and shaded with burlap to prevent leaf burn. The leaves were kept from wilting by frequent sprinkling. The sand temperature was about 75 degrees F.

Practically all of them rooted, and on April 24, 1930, they were transplanted bare root and with the original three or four leaves intact, to the Upland nursery. Despite the rocky nature of the soil only about one per cent died, and the rest developed into excellent plants.

The history of the budlings is as follows: The seeds for the grapefruit stock were obtained from a large seedling, planted about 1888, on the E. P. Jochimsen place, La Verne. They were planted in a lath-house in May 1929, and in April 1930 the seedlings were dug, fumigated, and planted in the Upland nursery. The larger seedlings were budded in the fall of 1930 and the rest the following spring.

In 1932, when the trees were ready for the orchard, the cuttings, then 2 years old, were appreciably larger than the budlings, which consisted of a 3-year-old rootstock and a 1-year-old scion. Probably the main reason why the budlings developed more slowly was that they received two rather severe prunings, the first when the rootstock seedlings were transplanted from the seedbed to the nursery and the second when the seedling top was cut off to force the lemon bud into growth.

The trees for the Oxnard plot were grown on the Utt Development Company Ranch. Cuttings and buds were taken from one parent tree, and the seeds for the sweet orange rootstock came from one tree.

## ORCHARD PLANTING

As previously stated, four plots were established in the Upland area, three in the spring of 1932 and one in 1933. The reason for delaying the latter was that the cooperator favored 2-year-old scions or "buds" as they are commonly called. The total number of trees was 136 for one plot, 144 for each of two plots, and 199 for the fourth. Half were cuttings, and half budlings. The trees were planted bare root. No replacements were required.

In this connection it should be mentioned that lemon cuttings do not develop tap roots like seedling rootstocks. In the Upland planting the number of lateral roots per cutting ranged from 1 to 12. On 2-

year-old cuttings roots up to 6 feet in length were observed, and consequently, in removing the plants from the nursery, a large percentage of the rootsystem was lost. In the budlings the loss was much less because the laterals, which grow from the tap root, are shorter and more numerous.

The Oxnard plot, planted in 1936, consisted of 24 of each of cuttings and budlings. They were transplanted balled.

#### TREE CONDITION

For the first three years in the orchard the cuttings were more vigorous than the budlings. During the fourth year, however, several cuttings in the Upland plots showed signs of weakness; they became less densely foliated, and the leaves were mottled in varying degrees. At the end of the fourth year this condition became more general, and all observers agreed that the budlings were not only more vigorous than the cuttings but that they also showed much less variation in tree condition.

Now, after 16 years, only 16 per cent of the cuttings in one plot and 30 per cent in another are comparable in size and vigor to the average budling.

The situation in the Oxnard plot is even less encouraging. Here the difference in favor of the budlings after 12 years is even greater than in Upland, and for several years past the trees have been considered a liability.

#### RELATIVE HARDINESS

Besides less vigor and, as will be shown later, smaller yield, the cuttings also proved to be less hardy than the budlings. The January 1937 freeze occurred when the trees in Upland started to produce commercial crops. Since none of the four plots were equipped with heaters, the trees suffered severe damage. It was soon evident, however, that the cuttings were damaged more than the budlings. In fact, in two of the plots the cuttings were removed because they were not considered worth saving; the budlings in these plots made a good recovery. In the other two plots, where the damage was not quite as severe, the budlings recovered more rapidly than the cuttings. Also of interest was the observation that for two years after the freeze the leaves of the cuttings were more or less mottled, while those of the budlings were normal.

#### YIELD

The trees produced light crops in 1935 and 1936, and a good crop was in prospect when the January 1937 freeze occurred. As already mentioned, it eliminated two of the plots. In 1939 yields were again recorded and continued until 1942 when, due to the labor shortage brought on by the war, no further records could be obtained. However, periodic observations were continued, and they indicated no change in the relative position of the cuttings and budlings.

The yield in the two plots is shown in Fig. 1. It should be mentioned that the graphs do not show total yield for every year because

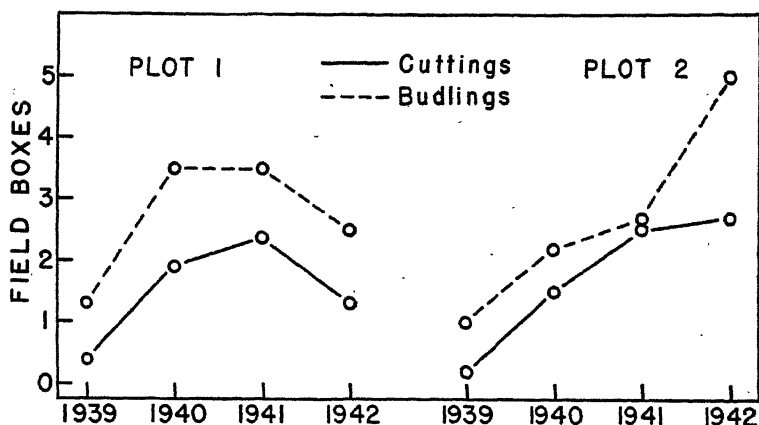


FIG. 1. Comparative yield of cuttings and budlings in Upland.

through oversight some of the pickings were not recorded. For example, in plot 1 the 1941 and 1942 yield represents only five and three picks respectively, while in plot 2 the record is complete for these two years.

It will be seen that the budlings consistently outyielded the cuttings. The difference varied from a fraction of a box to over two boxes per year where all pickings were recorded.

As to the bearing habit, the two types of trees behaved similarly; when the pick was heavy for one, it was also relatively heavy for the other. No data on fruit quality were obtained, but observers agreed that the cuttings produced a higher percentage of tree-ripe fruit than the budlings. This is understandable in view of the fact that the foliage of the cuttings was comparatively sparse and had a tendency to mottle.

No records were obtained from the Oxnard plot, but it was obvious even to the casual observer that the difference in quantity and quality was even more pronounced than in the Upland plots.

#### DISCUSSION AND CONCLUSION

From the foregoing it is evident that Eureka lemons on their own roots have nothing to recommend them. The Upland trees, now in their sixteenth year, do not show any indications that the cuttings will overtake the budlings in the immediate future. The Oxnard cuttings show even less promise. In addition to these five plots, cuttings were scattered in about 10 orchards between 1928 and 1931. Also, individual growers became interested and planted them for observation. These plantings were under varying soil and climatic conditions, and they included many types of lemons, from the early, ever-bearing, relatively weak types, generally classed as Eureka, to extremely vigorous ones which come into production rather late and which produce practically only one crop. However, the latter, although vigorous, proved to be very susceptible to gummosis. It is an interesting fact



that none of the Eureka cuttings and budlings in Upland developed this disease, although many trees on sweet stock in the same orchard were affected.

The reason for the inferiority of the Eureka cuttings is not clear unless it is assumed to be due to inherent weakness which is partly overcome by budding on a rootstock of a different species. The theory that the absence of taproots is a factor is untenable. Trees removed after the 1937 freeze showed that neither the grapefruit nor sweet orange rootstocks maintained a taproot system for more than 5 years. Moreover, the cuttings were as good as the budlings for the first few years when the latter still had a very pronounced tap root. Nor is there any evidence that the number of roots was a factor. When planted in the nursery, the number of roots varied from 1 to 12, but this fact bore no relationship to the size and condition of the trees. Of interest was the observation made when the cuttings were removed from two plots after the 1937 freeze. It was then noted that the number of main roots varied only from five to eight. Apparently those trees which originally had only one root developed at least four more main roots, while those with 12 lost at least four, probably due to crowding.

#### SUMMARY

Eureka lemons on their own roots, after 16 years, proved to be less vigorous, less hardy, and less productive than progenies of the same parents budded on grapefruit and sweet orange rootstocks.

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## Compositional Factors Affecting the Edible Quality of Oranges<sup>1</sup>

By WALTON B. SINCLAIR and E. T. BARTHOLOMEW, *University of California Citrus Experiment Station, Riverside, Calif.*

THE soluble solids of citrus fruits are composed chiefly of soluble sugars and organic acids. These two classes of substances control primarily the sweet and sour sensations of taste. The other soluble constituents that are present in the juice in relatively low concentrations are, nevertheless, important in determining fruit quality. Flavor varies not only with concentration of total soluble solids, and with relative amounts of sugars and acids, but also with other independent variables. Differences in amounts of aromatic substances, for example, may cause noticeable differences in palatability in oranges having the same concentration of total soluble solids. Although the major sensations of taste (sweetness, sourness, saltiness, and bitterness) may be masked by small quantities of aromatic substances, the chemical components and their biochemical relationships can be interpreted in part in terms of the edible quality of the fruit.

While studying the influence of rootstocks on the composition of citrus fruits, the authors deemed it important to investigate the changes that occur in the soluble constituents of the juice during growth and maturity of the fruit, and especially to correlate the concentration of one soluble constituent with that of another for the purpose of determining their physiological and biochemical relationships. Most of these results have already been published (13). Since these data were obtained, the organic acids of citrus fruits have been identified and quantitatively determined, and the factors affecting the pH and buffer properties of the juice are more clearly understood (14, 15, 16, 17). This additional information enables the authors to evaluate, on a biochemical basis, the acid properties of the juice with respect to other soluble constituents in the fruit.

The problem in the present investigation has been to correlate data on total soluble solids, pH, and total acidity of orange fruits with data published by other investigators on the taste and flavor of fruits. Attention is drawn to certain chemical changes that occur in the fruit and produce changes in these constituents of the juice. The soluble constituents other than sugars and acids are discussed in relation to taste of the fruit.

### MATERIALS AND METHODS

The methods of fruit sampling and the analytical procedures used in these studies are the same as those described by the writers for their rootstock studies (13). Most of the fruit samples for juice analysis were taken over a period of 7 years (1936 to 1942) from one Valencia grove and one Washington Navel orange grove in the interior valley section of southern California, and from one Valencia grove near the coast. These groves had been set out for the rootstock studies referred

<sup>1</sup>Paper No. 565, University of California Citrus Experiment Station, Riverside, California.

to above. Each of the 14 plots of 10 trees each in the Valencia grove in the interior represented a different rootstock. The 14 rootstocks were duplicated in the 14 similar plots in the Valencia grove near the coast. Thirteen of these rootstocks and one other stock were represented in the 14 plots in the Washington Navel grove in the interior. When the rootstock project was begun, great care was exercised in order to obtain uniform buds and stocks.

In all tests the fruits were halved and the juice was extracted from both halves by means of a hand reamer. Both halves of the fruits were used because it is now generally known (1) that there is a higher concentration of soluble constituents in the styler half than in the stem half of the fruit. The various organic analyses of the juice were made (13) after it had been thoroughly mixed and the portions for analysis had been strained and centrifuged.

The data presented are mostly for fruits of Washington Navel and Valencia orange on trifoliate orange and Rough lemon rootstocks. These two stocks were selected in preference to others because compositional differences in the fruits are sufficiently large to illustrate the points discussed.

## RESULTS

*Relation of Total Soluble Solids and Total Acids to Fruit Quality:*—In a previous paper (1) the authors drew attention to the high correlations (Navels, +0.9700; Valencias, +0.9219) between total soluble solids and total sugars in the juice of both the Washington Navel and the Valencia orange. This was to be expected, as sugars constitute 75 to 80 per cent of the total soluble solids in orange juice. Since total soluble solids, which are highly correlated with total sugars, are easily and quickly determined in most biological materials by means of the refractometer, investigators in horticulture use the refractometer rather than sugar determinations in fruit-quality studies. The proportion of total sugars to total soluble solids is the important thing, and not the absolute amount of total soluble solids in the juice. It so happens, however, that in most fruits the total sugars make up the major portion of the total soluble solids in the juice.

It is not surprising, therefore, that in most fruits there is a high correlation between edible quality and total soluble solids, as shown by the results of many investigations. Rosa (12) has found that sweetness, as influenced by the amounts and kinds of sugars, is the most important factor in the edible quality of melons. Since the total sugars accounted for nearly all the total soluble solids, the latter is highly correlated with quality. Porter, Bisson, and Allinger (10) have shown that high quality in watermelons is largely dependent upon high total sugar content. In the varieties that they studied, the total sugar content amounted to approximately 85 per cent of the total soluble solids.

Currence and Larson (2) found a significant variation in the reactions of testers engaged in tasting muskmelon fruits, and brought out the difficulty of satisfactorily classifying the fruit by tasting. In estimating the mean of several tastes in the organoleptic tests, three experienced testers were not superior to three selected at random.

These investigators did show, however, a significant correlation between quality score and different refractometer readings between fruits. Harding and Wadley (3), in experiments with orange fruits, found high correlations between palatability and both acid and solids; and in their organoleptic tests, tasters showed statistically significant differences. It should be mentioned, however, that mathematically significant differences between two sets of biological data are not always of practical importance. The same is true of low correlation coefficients, which may be statistically significant but of little practical value.

It has been noted earlier (13) that the concentration of sugars increases and the concentration of acids decreases in orange juice during growth and maturity of the fruit. A similar relation prevails between total soluble solids and total acidity. Nevertheless, it is clear from the data in Fig. 1 that large changes can occur in total acidity

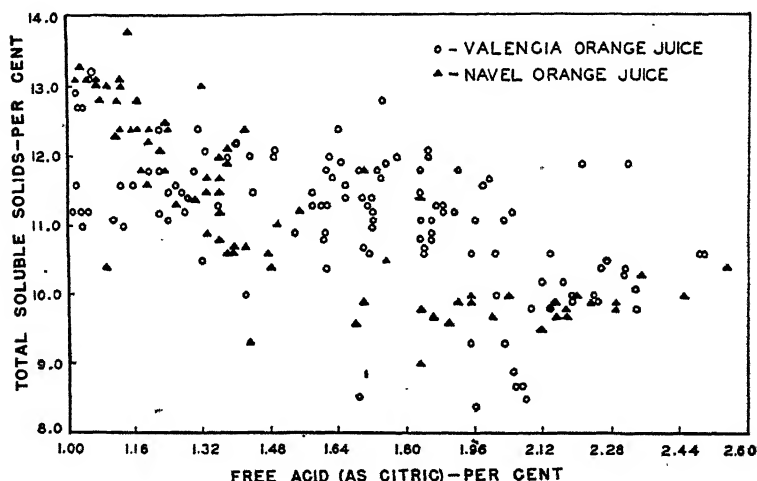


FIG. 1. Relation of total soluble solids to total acids in juice of Valencia and Washington Navel oranges. Fruit maturity ranged from immature (green) to fully mature. (For picking dates of samples, see Figs. 2 and 3.)

with only slight changes in total soluble solids. The reverse is also true. This wide range in acid concentration (1 to 2.6 per cent) shows that the juice samples were from fruits ranging from immature (green) to fully mature. These data explain why in many instances high concentration of soluble solids at maturity is not necessarily correlated with a correspondingly low concentration of acids. In general, however, significant negative correlations (Valencias,  $-0.5390$ ; Navels,  $-0.4386$ ) exist between the total soluble solids and the total acids of orange juice (1). Although it is generally true that the acids decrease and the soluble solids and sugars increase as the season advances, large variations in soluble solids and sugars of the juice frequently occur with only slight changes in total acids. For example, Fig. 1 shows that orange juice containing 11.0 per cent total soluble

solids may have a total acidity ranging anywhere from 1.0 to 2.6 per cent; or, conversely, that juice having a total acidity of approximately 1.8 per cent may contain anywhere from 8.5 to 13.0 per cent total soluble solids. Results of this kind indicate the chances for error in using the ratio of soluble solids to acids as the sole criterion of maturity and quality of oranges. Slight changes in the percentage of acids result in large changes in the ratio without markedly affecting the quality of the juice.

*Changes in pH and Free Acid of the Juice During Fruit Growth:—* In a previous study (17) it was shown that the maximum amount of free acid in Valencia orange fruits developed early in the season and changed very little from that time on. The concentration of free acid in the juice (milligrams per milliliter), however, decreased considerably during fruit growth. The decrease in free acidity with the corresponding increase in pH of juice of Valencia and Navel oranges from trifoliate and Rough lemon rootstocks is strikingly shown in Figs. 2 and 3. With both Valencia and Navel oranges, the free acid is significantly higher in juice of fruits from the trifoliate stocks. On the average, this difference in free acid is just about as large as any that occurred between fruits from the various rootstocks. At all stages of growth designated on the graphs (Figs. 2 and 3), the samples from

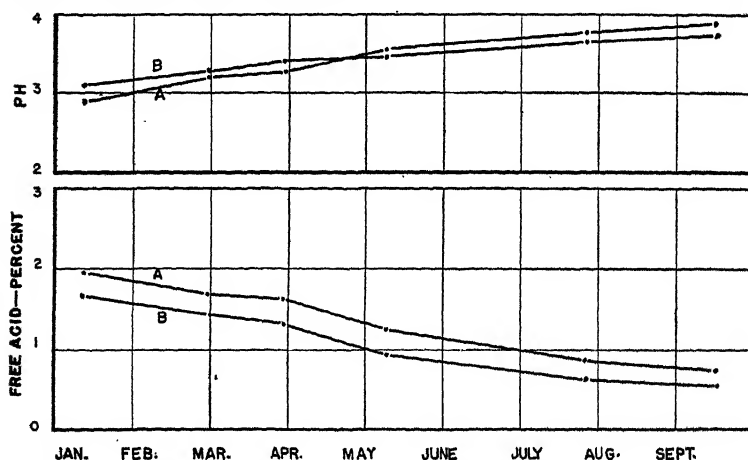


FIG. 2. Changes in pH and in concentration of free acid of juice of Valencia oranges during maturation of the fruit. Samples were taken at intervals from Valencia trees budded on (A) trifoliate orange and (B) Rough lemon stocks.

the trifoliate stocks were higher in free acid than those from Rough lemon. Although the pH values increased, correspondingly, with the growth of the fruit, the differences in pH of the juices of fruits from the two stocks were relatively small.

These small differences between the two pH curves in Figs. 2 and 3 can be attributed to the large buffer capacity of the juices and the low degree of dissociation of the organic acids contained in the fruits.

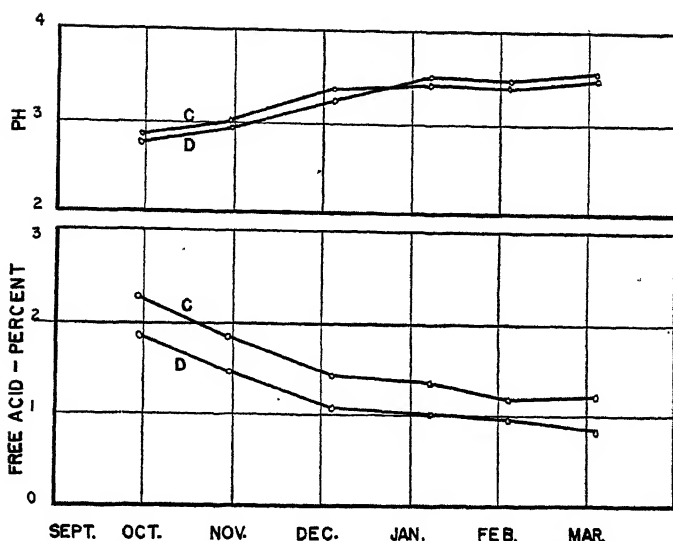


FIG. 3. Changes in pH and in concentration of free acid of juice of Washington Navel oranges during maturation of the fruit. Samples were taken at intervals from Navel trees budded on (C) trifoliate orange and (D) Rough lemon stocks.

Pure solutions of weak acids can undergo considerable dilution without any great change in pH, provided the dissociation constant ( $K_a$ ) is small and the undissociated residue sufficiently high to keep  $K_a$  constant. The pH of systems like that of orange juice is governed chiefly

by  $pK_a$  (dissociation exponent) and the ratio of  $\log \frac{\text{salt}}{\text{acid}}$ . The vari-

ation of  $pK_a$  with concentration changes occurring in the juice is very slight, and in this discussion it may therefore be assumed to be a constant. This leaves the factor  $\log \frac{\text{salt}}{\text{acid}}$  as the only one that may vary

the pH. The dilution of orange juice with water may change the free-acid (titratable acidity) concentration considerably without changing

the value of  $\log \frac{\text{salt}}{\text{acid}}$ , as the salt and acid would be diluted or concentrated in the same proportions. The pH of the juice could therefore

remain nearly constant, but the concentration of the acid would vary over a wide range. This is what happens to a greater or lesser degree in orange fruits during growth and maturity. With the advance of the season, the gradual increase in pH is the result of changes in the ratio

of  $\log \frac{\text{salt}}{\text{acid}}$  caused either by a decrease in free acid or an increase in salt formed from the organic acids and inorganic cations.

*Correlation of pH with the Free Acid of the Juice:*—In the course of the previous investigation (13) it was necessary to make a large number of determinations of pH and of free acid (titratable acidity) on juice of oranges from samples collected at various stages of maturity from the Valencia and Washington Navel rootstock plots in the interior and coastal sections. These data, as represented in Fig. 4, show the relation between pH value and titratable acidity. It can be observed that the pH values were determined over a wide range of free-acid concentration (2.60 to 0.70 per cent), the samples representing immature (green) to fully mature fruit.

The data show that the pH value of orange juice bears a definite relation to the titratable acidity, if compared over a wide range of acid concentration. This relation is not so definite, however, over shorter ranges of acid concentration, where two samples having fairly large differences in acidity may have the same pH value. For example (Fig. 4), orange juice having a pH value of 3.20 may have a titratable

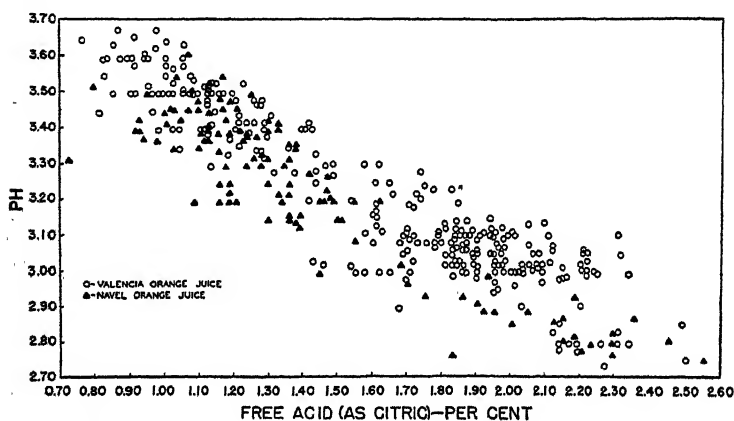


FIG. 4. Relation of pH to free acid (titratable acidity) in the juice of Valencia and Washington Navel oranges from two different climatic environments and from 14 different rootstocks. Fruits ranged from immature (green) to fully mature. (For picking dates of samples, see Figs. 2 and 3.)

acidity ranging from approximately 1.10 to 1.85 per cent; or, conversely, juice having a titratable acidity of approximately 1.43 per cent may yield pH readings ranging from 3.0 to 3.43. Under these conditions the pH value does not indicate the amount of free acid present, nor does a given free-acid value represent a definite pH value. The data reported in Fig. 4 represent extreme variations in pH values, as the determinations were made on samples from 14 different rootstocks from two different climatic environments.

*Relation of pH and Total Acids to Taste:*—The acidity of citrus fruits is highly associated with quality. Lemons of good quality have a relatively high titratable acidity (50 to 60 milligrams citric acid per milliliter of juice). Oranges of good quality have an acidity (8 to 12 milligrams citric acid per milliliter of juice) which is usually related

to the total-soluble-solids content in terms of a minimum ratio of total soluble solids to acids (8:1). The physical and chemical properties associated with high quality of grapefruit are accompanied by low acid content of the juice (10 to 12 milligrams citric acid per milliliter of juice). These facts bring up the question as to the status of pH and total acids in relation to quality in terms of taste. The organoleptic tests may reveal an integrated result of all the constituents in the juice affecting taste, but certain phases of this problem are worthy of a discussion from a physical and chemical point of view.

The data in Figs. 2 and 3 show that during the growth of the fruit from the very immature to the mature state, the titratable acidity (concentration of free acid) decreased more than 50 per cent with less than

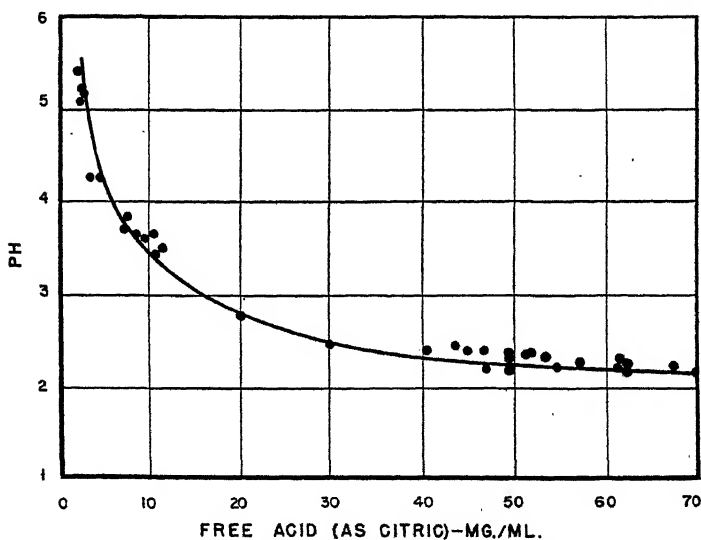


FIG. 5. Changes in pH with variations in concentration of free acid in lemon juice during fruit development.

one unit change in pH. These changes are more pronounced in lemons (Fig. 5) than in oranges. After the concentration of acid attains approximately 40 milligrams per milliliter of lemon juice, the amount can be nearly doubled with only 0.3 of a unit change in pH. It is realized in this connection that the pH term is a logarithmic function, and one unit change in pH represents a tenfold change in hydrogen-ion concentration. As the organic acids that occur in most fruits have comparatively low dissociation constants, a tenfold change in hydrogen-ion concentration is not so easily discerned by organoleptic test. In these experiments, the active acidity of mature orange juice did not vary more than 0.5 pH.

From the above experimental data, it appears that the decrease in sour taste during the ripening of citrus fruits is influenced by the decrease in titratable acidity, as well as by changes in pH values. The sour taste of juices from mature citrus fruits can be greatly reduced



by dilution without any marked change in pH. In a previous paper Sinclair and Eny (14) showed that the addition of sucrose to lemon juice up to 50 per cent did not change the pH of the system. That physiological factors are involved is shown by the fact that the sucrose reduced the sour taste but not the pH of the lemon-juice samples. The degree of sweetness markedly influences the sensation of the sour taste of citrus juices without altering either the pH or total acidity.

It is not in the realm of this paper to discuss fully the physiological factors affecting taste. The subject is very complex and needs investigating. A brief mention should be made, however, of the pioneer studies of Richards (11) and Kastle (6). In short, these investigators found, independently of each other, that the sour taste of an acid is qualitatively related to its degree of dissociation; and that, with considerable accuracy, the sour taste of an acid completely disappeared at its neutralization point. This would mean that sour taste depends upon the hydrogen-ion concentration (pH). These findings are not entirely in harmony with the results reported in the present paper. The fact that citrus juices can undergo large changes in titratable acidity with relatively small changes in pH is evidence that factors other than the dissociation constants of the acids are involved in determining sour tastes of the juices. It appears, therefore, that the sour taste of citrus juices is influenced as much by total acidity as by pH. These results are in partial agreement with those of Harvey (4) and of Harvey and Fulton (5), who concluded that total acidity is more important than the relatively small fluctuations in the hydrogen-ion concentration in the sourness of tomatoes.

The investigations of Paul (9) are of interest here in that he found that acids with the same degree of dissociation had different degrees of sourness at equivalent concentrations. Apparently, differences in taste of weak organic acids of approximately the same  $K_a$  are due in part to the undissociated portion of the molecule. Paul (9) arranged the organic acids of equivalent concentrations in the following order of increasing sourness: carbonic acid, cream of tartar, acetic acid, lactic acid, hydrochloric acid, and tartaric acid. Acid solutions that contain buffers have a greater sour sensation than solutions of the pure acid at the same hydrogen-ion concentration (8).

*Soluble Constituents of the Juice, Other than Sugars and Acids, in Relation to Taste:*—About 15 per cent of the soluble constituents of orange juice are other than sugars and acids. This fraction consists of inorganic compounds, amino acids, ascorbic acid, and small amounts of pectins, essential oils, esters, glucosides, etc. Substances in this fraction are relatively and chemically unstable. The soluble sugars and acids of citrus juices are stable compounds. The occurrence of off-flavors in either natural or processed orange juices is in no small measure due to oxidation and decomposition of substances in this relatively small fraction of the soluble solids.

In general, taste is composed of the four distinct sensations of sweetness, sourness, saltiness, and bitterness. Each sensation is localized in a particular region of the tongue, has its own sensory end organs, and receives its particular chemical stimuli. It follows, then, that small

concentrations of substances such as essential oils, esters, and decomposition products of amino and fatty acids (7) would greatly affect the taste and flavor of citrus juices. Statistical studies based on the results of tasters are of some value in determining an integrated effect of all the soluble substances on the various taste sensations.

Future biochemical research on this problem will be concerned with the determination of the numerous soluble substances that exist in citrus fruits in very small concentrations, and the evaluation of the results in terms of edible quality of the fruit (taste and flavor).

#### SUMMARY

The high correlation between total soluble solids and edible quality in orange fruits is the result of the high sugar content, which comprises 75 to 80 per cent of the total soluble solids. Since total soluble solids are highly correlated with total sugars, refractometer readings are usually employed, rather than sugar determinations, in fruit-quality studies. The proportion of total sugars to total soluble solids, not the absolute amount of total soluble solids in the juice, is the factor primarily affecting the sensation of sweetness.

Although the total acids decreased during the growth and ripening of the fruit, while total soluble solids increased, large fluctuations in total acids occurred without change in total soluble solids, and vice versa. Significant negative correlations were found to exist, however, between total soluble solids and total acids.

Owing to the relatively high buffer capacity of orange juice, large fluctuations in titratable acidity occurred without change in pH, but over a wide range of acid concentration (0.70 to 2.60 per cent) the pH increased with a decrease in acidity.

During the growth of the fruit from the very immature to the mature state, the titratable acidity (concentration of free acid) decreased more than 50 per cent with less than one unit change in pH. The decrease in sour taste during the ripening of orange fruits is greatly affected by the decrease in titratable acidity, as well as by changes in pH. After the fruit reaches maturity (ratio of total soluble solids to acids, 8:1), the relatively small changes in pH occurring in the fruit from then on are hardly detectable in organoleptic tests.

The sweet and sour taste sensations of orange juice are due to the soluble sugars and the free acids, and are obviously highly correlated with edible quality. Soluble solids (other than sugars and acids), such as essential oils, esters, and amino acids, are important in the taste sensations, but the identification and determination of these constituents are subjects for future research.

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## Preliminary Studies on the Effects of 2,4-D Sprays on Preharvest Drop, Yield, and Quality of Grapefruit<sup>1</sup>

By W. S. STEWART and E. R. PARKER, *University of California Citrus Experiment Station, Riverside, Calif.*

RECENT studies (3) indicate that the application of 2,4-dichlorophenoxyacetic acid (2,4-D) to Valencia and Washington Navel orange trees reduces preharvest fruit drop 25 to 96 per cent. Results of similar studies on grapefruit in two field experiments, one at the University of California Citrus Experiment Station, Riverside, California, and the other at the Rancho Sespe, Fillmore, California, during the summer of 1946, are reported here.

### EXPERIMENTAL PROCEDURE AND RESULTS

*Experiment at Riverside:*—This experiment was established on June 3, 1946, in a randomized block design with six replications, each plot consisting of a single grapefruit tree. Since this experiment was superimposed on a rootstock experiment, the trees in the different blocks were on different rootstocks.

The trees were sprayed between 6:00 and 10:00 a. m. June 3, 1946. Test trees were sprayed with water solutions of 5, 25, 75, or 225 parts per million 2,4-D in the form of ammoniumdiethanol 2,4-dichlorophenoxyacetate. Control trees were sprayed with water only. A drenching spray was applied at 300 pounds pressure per square inch, using ordinary orchard spray guns with No. 8 discs in the nozzles.

All fruit on the ground was removed immediately after the spraying. Subsequent counts of fallen fruit were made at intervals of 2 weeks. Harvesting occurred on August 26, 1946, in the approximate middle of the commercial harvest season. The harvested fruit was counted, and it was thus possible to calculate fruit drop as percentage of fruit on the tree at the beginning of the experiment. One apparently typical block of treatments was not harvested in August, but was retained, with the fruit on the trees, so that further information on the duration of the effect of the treatments might be obtained.

At the time of spraying, in June, 1946, the tree bore nearly mature fruit as well as young fruit between 4 and 7 centimeters in diameter that would mature the following year (about July, 1947).

It was found that each of the 2,4-D sprays reduced the drop of mature fruit in the 1946 harvest, and that the amount of reduction was directly related to the concentration of 2,4-D in the spray (Fig. 1 and Table I). From the time of spraying (June 3) until harvest (August 26), a period of 12 weeks, the fruit drop from the non-sprayed trees amounted to 15.6 per cent of the crop. In comparison, there was a reduction of 53 per cent in fruit drop of trees sprayed

<sup>1</sup>Paper No. 570, University of California Citrus Experiment Station, Riverside, California.

The authors wish to express their appreciation to Messrs. C. B. Cree, C. F. Hammon, and H. Z. Hield for their assistance in these studies.

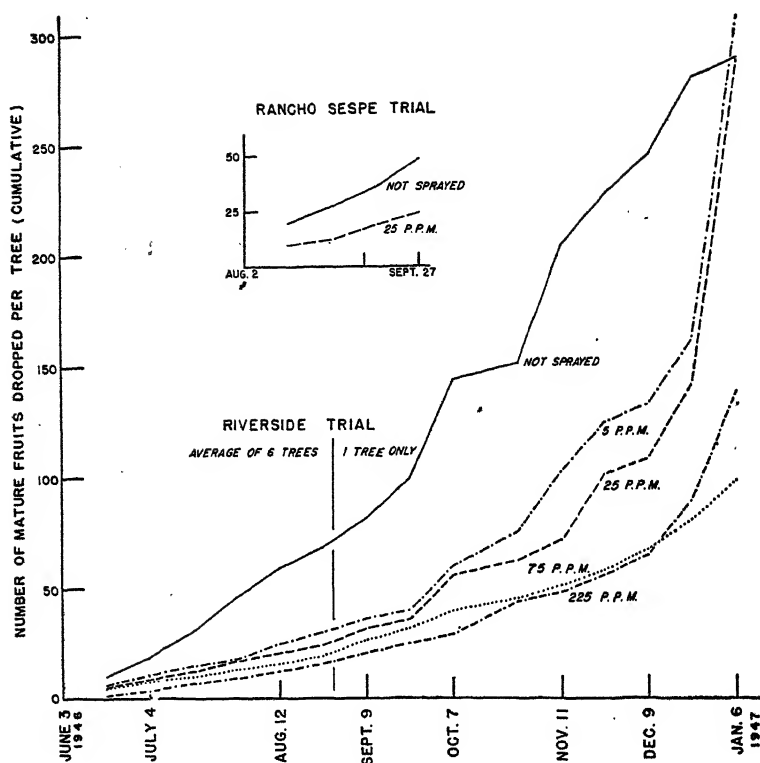


FIG. 1. Drop of mature grapefruit from nonsprayed (control) trees and from trees sprayed with water solutions of 5, 25, 75, and 225 parts per million 2,4-D at Riverside, California. Note that with minor exceptions near the end of the experiment reduction in fruit drop is directly related to concentration of 2,4-D in the spray. The insert shows drop of mature fruit from nonsprayed (control) halves of trees and from halves sprayed with water solution of 25 parts per million 2,4-D at Rancho Sespe, Fillmore, California.

with 5 parts per million 2,4-D, and of 65 per cent in that of trees sprayed with 25 parts per million 2,4-D. Although still greater reductions were obtained with sprays containing 75 and 225 parts per million 2,4-D, certain undesirable effects of these high concentrations, described below, appeared to render them impractical for commercial use. If fruit drop is expressed as percentage drop of the fruit on the tree at the time of spraying a curve similar to Fig. 1 is obtained. This results from the number of fruits per tree at the beginning of the experiment being approximately the same in the various treatments.

Laboratory tests were made on the juice of samples of fruits picked at intervals of 2 weeks during the period from June 17 to August 12, 1946. The percentages of soluble solids (degrees Brix, by refractometer) and of acid (as citric), and the ratio soluble solids/total

TABLE I—PREHARVEST DROP OF MATURE FRUIT FROM GRAPEFRUIT TREES SPRAYED WITH WATER SOLUTIONS OF 2,4-D

2,4-D in Spray (Ppm)	Number of Fruits Dropped	Number of Fruits Harvested	Fruit Drop as Per Cent of Total Number of Fruits on Trees When Sprayed	Per Cent Reduction in Fruit Drop of Sprayed Trees, Compared With That of Controls
<i>Experiment at Riverside*</i>				
None (control)	68	367	15.6	—
5	30	383	7.3	53.2
25	24	413	5.5	64.7
75	19	437	4.2	73.1
225	16	460	3.4	78.2
<i>Experiment at Rancho Sespe, Fillmore†</i>				
None (control)	48	251	16.1	—
25	24	283	7.8	51.6

\*Trees sprayed June 3, 1946, with 2,4-D as ammoniumdiethanol 2,4-dichlorophenoxyacetate; fruit harvested August 26, 1946.

†Tree halves sprayed August 2, 1946, with 2,4-D as ammonium 2,4-dichlorophenoxyacetate; fruit harvested September 27, 1946.

acid, were obtained on carefully collected samples of fruit of uniform size. These are common commercial indices of citrus fruit quality. No reduction in total soluble solids and no increase in total acidity were observed as a result of treatment with 2,4-D. The ratio was not reduced. There was also no significant change in pH of the juice. These data do not indicate any undesirable effects of the 5 and 25 parts per million 2,4-D sprays on fruit quality.

In the one block that was not harvested in August, fruit-drop counts were continued at intervals of about 2 weeks until January 6, 1947. This was 19 weeks after the period of commercial harvest and 31 weeks after the date of treatment. Because of lack of replication of treatments, the observations made subsequent to August 26 are more variable than those made earlier. They indicate, however, that the 2,4-D sprays were effective in reducing fruit drop for a total period of at least 26 weeks, and that during this time the effects were positively correlated with the concentrations of the spray. Soon thereafter the effects of the more dilute concentrations of 2,4-D (5 and 25 parts per million) appeared to wear off, and the trees treated with these sprays dropped their fruit rapidly during the next few weeks. The rate of fruit drop from trees sprayed with 75 and 225 parts per million 2,4-D was only slightly accelerated in the final period.

The sprays containing 2,4-D concentrations of 25 parts per million, or more, caused a curling and buckling of young, expanding leaves (Fig. 2). The degree of deformation was in proportion to the concentration of 2,4-D. Deformations caused by 75 and 225 parts per million 2,4-D tended to persist as the leaves grew; those caused by 25 parts per million 2,4-D were frequently temporary.

Mature leaves showed different responses to excessive concentrations of 2,4-D. Those sprayed with 225 parts per million 2,4-D developed irregular chlorotic areas (Fig. 2, E) which persisted for several months and then gradually disappeared.

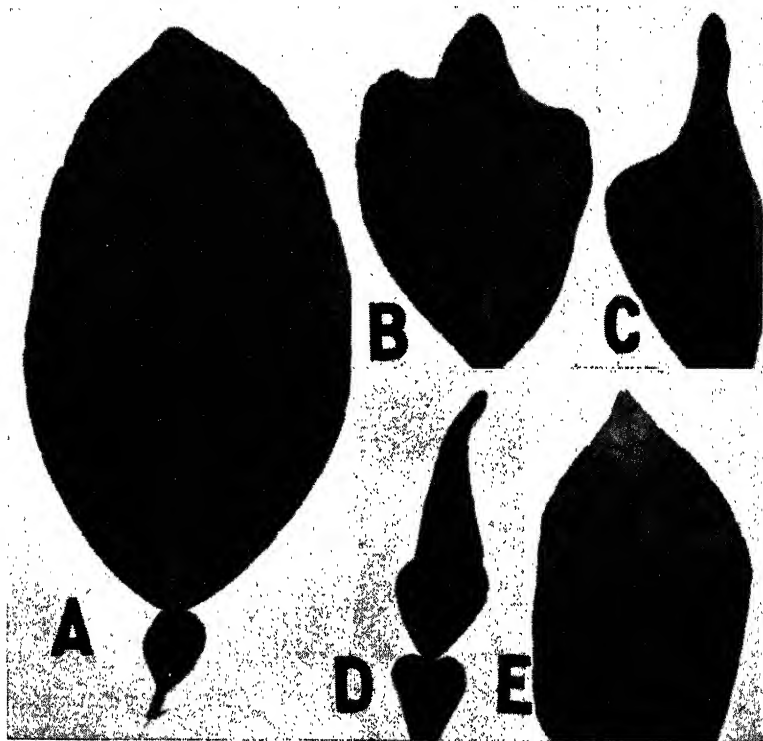


FIG. 2. Response of grapefruit leaves to water sprays containing 2,4-D. (A) Young, normal leaf from nonsprayed (control) tree. (B-D) Young leaves from trees sprayed with (B) 25 parts per million (C) 75 parts per million, and (D) 225 parts per million 2,4-D, showing buckling and curling. (E) Mature leaf from tree sprayed with 225 parts per million 2,4-D, showing irregular chlorotic areas.

On July 9, 1947, the fruit that was very small at the time of spraying (June 3, 1946) was harvested from all trees. Yields were determined by counting the fruit from each tree. For the different treatments, results were as follows:

2,4-D in Spray (Ppm)	Average Number of Fruits Per Tree
None (control)	237
5	327*
25	427†
75	337*
225	117†

\*The difference between this value and the control is significant at the 5 per cent level.

†The difference from the control is significant at the 1 per cent level.

Average fruit size, as indicated by the number of fruits per field box, was not significantly changed as a result of the treatments. Actually, however, some fruits from trees sprayed with 225 parts per million 2,4-D were greatly increased in size; others were very small. This effect was less apparent in fruit from trees sprayed with 75 parts per million 2,4-D and was not evident in that from the 5 and 25 parts per million treatments.

Besides causing abnormal sizes of fruit, the 225 parts per million spray induced some fruits to become cylindrical in shape; other fruits developed navels and grew thick, coarse rinds having excessively large oil glands (Fig. 3), while still other fruits developed dry, hard

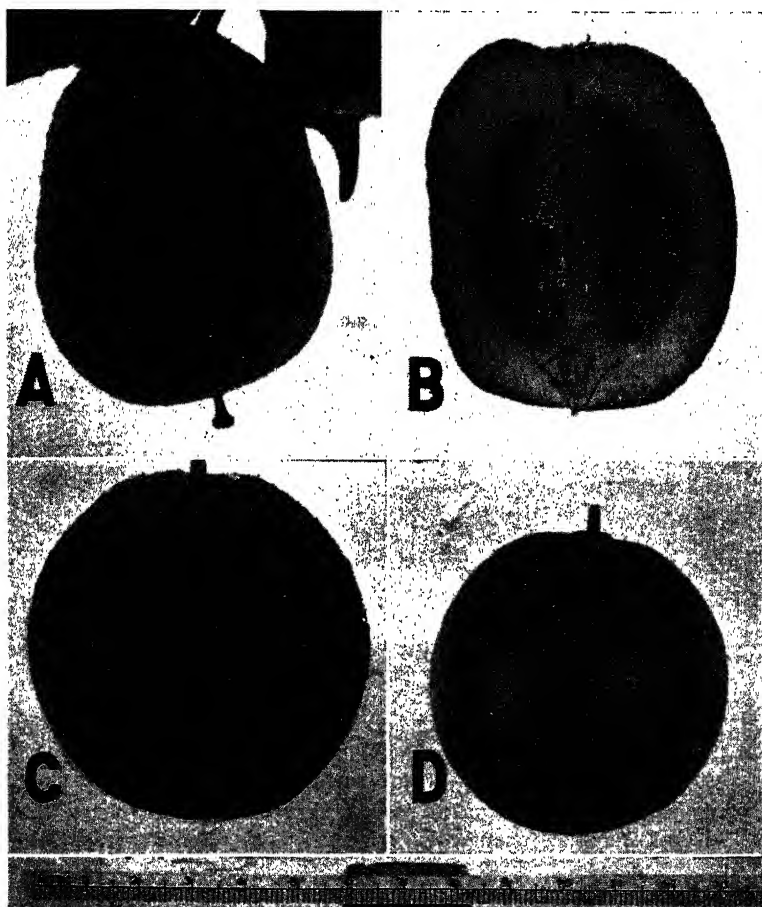


FIG. 3. Abnormal fruit induced by water spray containing 225 parts per million 2,4-D applied to grapefruit trees June 3, 1946. (A) Cylindrical fruit; (B) longitudinal section of same fruit, showing navel structure. (C) Fruit showing rough peel and enlarged oil glands. (D) Normal, non-sprayed (control) fruit.



juice vesicles. Similar responses to sprays containing high concentrations of 2,4-D have also been observed with Valencia and Washington Navel oranges (2).

At the time of harvesting the second crop (July 9, 1947), a composite sample consisting of eight fruits of uniform size was taken from each of the six trees per-treatment for measurement of fruit quality (Tables II and III). The fruits selected passed a size 80 grading

TABLE II—EFFECT OF WATER SOLUTIONS OF 2,4-D ON PHYSICAL QUALITY OF MATURE GRAPEFRUIT IN EXPERIMENT AT RIVERSIDE, CALIFORNIA\* . (TREES SPRAYED JUNE 3, 1946; FRUIT HARVESTED JULY 9, 1947)

Fruit Sample	2,4-D in Spray (Ppm)	Ratio, Length to Width	Rind			Juice		Rag, Per Cent by Weight	Specific Gravity	Number of Seeds	
			Weight (Grams)	Thickness (Mm)	Per Cent by Weight	Per Cent by Weight	Per Cent by Volume			Normal	Rudimentary
1	None (control)	0.947	150.2	8.24	46.7	45.3	35.8	5.84	0.8197	3.0	0.8
2	5	0.949	148.7	8.13	47.2	45.0	35.5	6.67	0.8174	2.7	0.8
3	25	0.973	153.9	8.06	48.6	41.6	33.0	8.31	0.8210	2.1	2.7
4	75	0.975	161.2	7.84	47.3	41.3	33.2	9.58	0.8358	1.8	6.1
5	225	0.981	162.7	6.26	45.0	37.7	31.5	14.90	0.8839	0.8	11.0
6†	225	0.988	318.9	9.86	47.4	36.6	28.5	13.70	0.8110	0.7	16.3
7‡	225	1.054	224.1	8.28	49.3	35.1	27.9	13.01	0.8313	0.8	14.4

\*Data given are averages. Unless otherwise stated, each sample consisted of 48 fruits of normal size (average diameter 9.08 cm).

†Abnormally large fruit; sample, 40 fruits.

‡Cylindrically shaped fruit; sample, 34 fruits.

TABLE III—COMPARATIVE ANALYSES OF JUICE OF MATURE GRAPEFRUITS FROM TREES SPRAYED WITH WATER SOLUTIONS OF 2,4-D IN EXPERIMENT AT RIVERSIDE, CALIFORNIA\* (TREES SPRAYED JUNE 3, 1946; FRUIT HARVESTED JULY 9, 1947)

Sample	2,4-D in Spray (Ppm)	Ascorbic Acid (Mg/100 Ml)	Total Acid as Citric (Per Cent)	pH	Soluble Solids (Per Cent)	Ratio, Soluble Solids to Total Acids
1	None (control)	29.0	1.48	2.88	10.49	7.11
2	5	31.7	1.42	2.89	10.64	7.50
3	25	31.7	1.45	2.90	10.65	7.37
4	75	33.4	1.43	2.90	10.95	7.67
5	225	35.2	1.36	3.00	12.44	9.13
6†	225	29.0	1.34	3.00	11.19	8.33
7‡	225	31.7	1.34	3.00	10.95	8.15

\*Unless otherwise stated, juice samples were from fruits of normal size (average diameter 9.08 cm); samples, 48 fruits each.

†Abnormally large fruit; sample, 40 fruits.

‡Cylindrically shaped fruit; sample, 34 fruits.

ring (9.5 centimeters in diameter) but not a size 96 ring (8.7 centimeters in diameter) and averaged 9.08 centimeters in diameter. The following differences were noted in these fruits with increase in concentration of 2,4-D in the spray treatment: an increase in the ratio of length to width, an increase in the number of rudimentary seeds, a decrease in the number of normal-appearing seeds, a decrease in rind thickness, an increase in soluble solids and pH of the juice, an increase in percentage of rag (tissue not passing through the vibrating screen of an electric juice extractor), and an increase in the specific gravity of the whole fruit. Samples of abnormally large fruits and of

cylindrically shaped fruits from the trees sprayed with 225 parts per million 2,4-D were also examined for fruit quality. These fruits generally showed even more extreme effects of high concentrations of 2,4-D in the spray than the normal-sized fruit (see Tables II and III).

*Experiment at Fillmore (Rancho Sespe):*—In this experiment alternate east or west halves of eight grapefruit trees were sprayed August 2, 1946, with a water solution containing 25 parts per million 2,4-D added as ammonium 2,4-dichlorophenoxyacetate. The treatment was applied as a drenching spray, care being taken to wet the fruit pedicels. Fruit was removed from under the trees immediately after the spraying. At 2-week intervals thereafter counts were made of fruit drop under the sprayed and nonsprayed halves of the trees. Fruit within a 2-foot strip between halves under each tree was not counted.

The nonsprayed halves of the trees dropped twice as much mature fruit as the sprayed halves during the interval between August 2 and September 27, 1946 (Fig. 1 and Table I). The difference in fruit drop was significant as judged by the *t* test. Analyses of fruit juice indicated no significant differences between nonsprayed and sprayed fruits in soluble solids, total acids, pH, or ascorbic acid. The young leaves in this experiment responded to the spray treatment in the same manner as those in the Riverside experiment.

## DISCUSSION

The results of these experiments indicate the possibility of using water sprays of 2,4-D to reduce preharvest fruit drop of grapefruit. In the Riverside experiment sprays containing only 5 parts per million 2,4-D were nearly as effective as those containing 25 parts per million. Sprays containing 225 parts per million 2,4-D reduced the following year's crop production and caused undesirable morphological responses in the fruit. Since some of the undesirable effects of the sprays were slightly discernible in fruits that had been sprayed while small with concentrations of 25 and 75 parts per million 2,4-D, those sprays containing less than 25 parts per million 2,4-D appear to be most feasible.

The significant crop increase observed in the Riverside plots the year following treatment with concentrations of 5, 25, and 75 parts per million 2,4-D is an effect that must be substantiated by further tests before being accepted as generally obtaining. The present data are not considered adequate for generalizations in this regard.

The development of navels in grapefruits sprayed with 75 or 225 parts per million 2,4-D suggests that the naturally occurring navels in certain citrus varieties may result from the presence of large amounts of one or more natural plant-growth regulators. This hypothesis is also supported by the observation that in the ovaries of parthenocarpic varieties of citrus (Washington Navel oranges, for example) the auxin content has been found to be higher than in corresponding seeded varieties (1).

In Navel oranges as in grapefruit, the development of rudimentary seeds has been observed to follow application of 2,4-D (2).

#### SUMMARY

Two field experiments are described in which water sprays containing 5 to 225 parts per million 2,4-D were applied to nearly mature grapefruit for control of preharvest fruit drop. Up to the middle of the normal harvest period fruit drop was reduced 52 to 78 per cent, the percentage of reduction depending on the concentration of 2,4-D. The reduction in fruit drop persisted after the usual harvest season.

No undesirable effects on the quality of the juice were noted as a result of the use of any of the sprays applied on the nearly mature fruit. Dilute sprays of 2,4-D appeared to have no commercially significant effects on the quality of the following year's fruit; but sprays containing 225 parts per million 2,4-D caused undesirable growth modifications in these fruits, as well as a reduction in yield. More dilute sprays seemed to increase the succeeding crop in one experiment, but sprays as dilute as 25 and 75 parts per million may have affected some fruit characteristics slightly.

The indications from these studies are that water sprays containing between 5 and 25 parts per million 2,4-D are promising as treatments for the reduction of preharvest drop of grapefruit. Sprays containing 5 parts per million 2,4-D were almost as effective as those containing 25 parts per million. Additional experiments are being carried out to determine the practical value of such sprays, and to answer certain questions regarding methods and effects of treatment.

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# Ascorbic Acid-Nitrogen Relations in Navel Orange Juice, As Affected by Fertilizer Applications<sup>1</sup>

By WINSTON W. JONES and E. R. PARKER, *University of California Citrus Experiment Station, Riverside, Calif.*

INVESTIGATIONS of the factors affecting the ascorbic acid content of plants have been numerous. Two factors appear to have marked influence on ascorbic acid content, namely, climate, or light (3, 4), and mineral (nitrogen) nutrition (1, 2, 5). Under conditions of relatively low light intensities light is apparently the more important factor (3), but under those of relatively high light intensities mineral (nitrogen) nutrition appears to be dominant. The published data are somewhat contradictory, however. An attempt has been made elsewhere (5) to integrate these factors.

Because of the relatively high light intensities found in southern California, nitrogen nutrition might be expected to be an important factor in ascorbic acid concentration. As a part of a study concerned with the influence of cultural and fertilizer practices on size and quality of navel orange fruit, a number of determinations have been made to ascertain whether the ascorbic acid content of the fruit has been affected.

## MATERIALS AND METHODS

The fruits for the present study were taken from trees in a navel orange fertilizer experiment at Riverside. This experiment, which has been described by Batchelor, Parker, and McBride (1) and by Parker and Batchelor (6) and is now (in 1947) in its twentieth year, includes a total of 44 treatments, each replicated four times. For the study reported here, trees of the 12 treatments listed in Table I were

TABLE I—FERTILIZER TREATMENTS OF NAVEL ORANGE PLOTS (1939-1947)

Treatment*	Pounds Nitrogen Applied Per Tree Annually
6. Winter cover crop only.....	0
2. N.....	3
3. N, P.....	3
4. N, P, K.....	3
5. N, K.....	3
18. N and winter cover crop.....	3
8. N, P, and winter cover crop.....	3
9. N, P, K, and winter cover crop.....	3
11. N, K, and winter cover crop.....	3
C. N, manure, and winter cover crop.....	3
31. Manure and winter cover crop.....	3
23. N and winter cover crop.....	5

\*Explanation of symbols: N = nitrogen, derived from urea, except in treatment 23, from  $\text{Ca}(\text{NO}_3)_2$ ; P = treblesuperphosphate; K = potassium sulfate.

selected. Since 1939, the rates of nitrogen application have been those indicated in the table.

Fruit samples were taken in February and again in March, 1947, each composite sample consisting of six fruits of uniform size from

<sup>1</sup>Paper No. 571, University of California Citrus Experiment Station, Riverside, California.

the north, south, east, and west sides of each of three trees, or a total of 72 fruits for each replication. For the four replications of each treatment the total number of fruits tested was therefore 288. Fruits were juiced and the juice of each composite sample was mixed. Ascorbic acid in the juice was determined by visual titration with a standard solution of sodium 2,6-dichlorobenzenoneindophenol. Nitrogen was determined by the micro-Kjeldahl method.

### RESULTS AND DISCUSSION

Since the results of tests on the samples taken in February and in March were similar, only those of the first date are reported here. The data are shown in Tables II, III, and IV, and in fig. 1.

TABLE II—NITROGEN AND ASCORBIC ACID IN JUICE OF NAVEL ORANGES FROM TREES RECEIVING VARYING AMOUNTS OF NITROGEN\*

Treatment No.	Nitrogen		Ascorbic Acid, Mg Per 100 Ml Juice
	Pounds Applied Per Tree Annually	Mg Per 100 Ml Juice	
6	0	116.2	83.0
2, 3, 4, 5, 18, 8, 9, 11, C, 31 (Mean)	3	163.4	70.5
23	5	181.0	68.5

\* $r = -0.875$ .

TABLE III—NITROGEN AND ASCORBIC ACID IN JUICE OF NAVEL ORANGES FROM TREES RECEIVING THE SAME AMOUNT OF NITROGEN

Treatment	Nitrogen, Mg Per 100 Ml Juice	Ascorbic Acid, Mg Per 100 Ml Juice
31.....	146.3	72.0
C.....	155.8	72.5
18.....	156.8	71.0
11.....	160.3	71.4
8.....	162.4	68.8
2*.....	166.2	70.0
5*.....	169.8	72.1
9.....	169.8	70.2
3*.....	172.9	66.4
4*.....	173.6	70.8
Mean.....	163.39	70.52
Difference required for significance at odds of:		
19 to 1.....	10.05	3.08
99 to 1.....	13.57	4.16

\*Without cover crop or manure.

TABLE IV—ANALYSES OF VARIANCE OF NITROGEN AND ASCORBIC ACID CONTENT OF JUICE OF NAVEL ORANGES FROM PLOTS RECEIVING THE SAME AMOUNT OF NITROGEN IN THE FERTILIZER

Source of Variation	Degrees of Freedom	Nitrogen		Ascorbic Acid	
		Mean Square	F	Mean Square	F
Total.....	39	—	—	—	—
Blocks.....	3	663.397	—	1.210	—
Treatment.....	9	305.848	6.378**	13.378	2.964*
Error.....	27	47.954	—	4.514	—
Organic matter effect†.....	1	1399.73	29.189**	12.61	2.794

\*\*Significant at 99 to 1 level.

\*Significant at 9 to 1 level.

†Plots with organic matter versus those without.

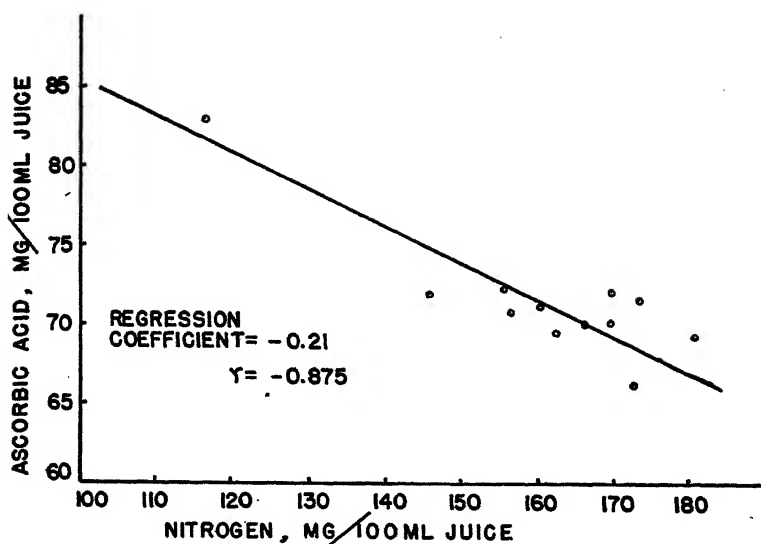


FIG. 1. Relation between ascorbic acid and nitrogen in juice of navel oranges supplied with different amounts of nitrogen in the fertilizer.

Juice of fruits from treatment 6 was found to be extremely low in nitrogen and high in ascorbic acid, whereas that from treatment 23 was high in nitrogen and low in ascorbic acid. When all treatments are considered, the correlation coefficient between ascorbic acid and nitrogen is  $-0.875$ , a value significant at the 1 per cent level. When only those treatments providing the same annual amount of nitrogen per tree (3 pounds) are considered, however, a different situation appears to exist. It was found that highly significant differences existed in the nitrogen content of juice of fruits from the different treatments in this group, as judged by analysis of variance. Likewise, significant differences in the ascorbic acid content were observed. The correlation coefficient between nitrogen and ascorbic acid for the fruits from these treatments is only  $-0.237$ , however, which is not significant.

We have no data that will adequately explain the differences in ascorbic acid and nitrogen in the juice of fruits of those trees receiving the same amount of nitrogen in the fertilizer. The differences in nitrogen in the juice are probably related to supplemental treatments other than nitrogen applied. Treatments 8, 9, 11, 18, 31, and C included organic matter, and the juice of fruits from those plots contained, on the average, significantly less nitrogen than that of fruits from treatments 2, 3, 4, and 5, which did not include organic matter (Table III). It is of interest to note that additions of organic matter markedly affected the permeability of the soil (7) and also increased yields of fruit (6). In the present studies, however, no effect on ascorbic acid content of the fruit juice could be ascribed to organic matter.

It appears from these studies that when the range of nitrogen in the juice is held within the narrow limits imposed by fertilizer treatments supplying the same amounts of nitrogen per tree annually, there are independent but significant variations between the amounts of ascorbic acid and nitrogen in the juice; but when the limits of nitrogen supply are widened, there is a correlation, the ascorbic acid in the juice varying inversely with the nitrogen. This is not unexpected. The correlation exists only when nitrogen is a limiting factor. It is difficult to ascribe the independent variations described above to light, since the trees were equally foliated and the fruit must have received similar exposure. This suggests that there are additional, but unknown, factors concerned in the metabolism of ascorbic acid.

#### SUMMARY

1. Under the conditions of this study, there was an over-all inverse correlation between nitrogen and ascorbic acid in the juice of navel oranges.
2. The amount of nitrogen in the juice varied with the amount applied in the fertilizer.
3. The addition of organic matter to those fertilizer treatments providing equal amounts of nitrogen per tree annually resulted in a highly significant decrease in nitrogen in the juice but had no effect on the ascorbic acid content.

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# Identification of Pear and Quince Rootstocks from Root-Pieces<sup>1</sup>

By G. S. RANDHAWA, *Ontario Agricultural College,  
Guelph, Canada*

**I**F the bud or graft-union of a dwarf pear tree is covered with soil, rooting will eventually take place from the scion. For this reason, shallow planting of dwarf pear trees has been recommended. Even if this advice is strictly followed, sometimes normal cultivation, after a time, raises enough soil to cover the union and scion roots result. In such cases the scion roots should be pruned away in order to maintain the dwarfing effect of the rootstock. It is important, therefore, to be able to distinguish pear roots from the quince roots.

## MACROSCOPIC TESTS

1. *Surface Color of Bark*:—Young pear roots were found to be reddish brown, whereas young quince roots were dull dark brown. In old quince roots this color was further deepened to a prominent blackish tinge. This proved to be a definite means of identification.

2. *General Growth Habit*:—Quince roots were finer, numerous, and for the most part, penetrated the soil horizontally. Pear roots, on the other hand, were strong and penetrated the soil vertically.

3. *Color of Inner Bark*:—The color of inner bark proved to be another useful means of identification of pear and quince roots. Pear roots were creamy white; quince roots were pearly white, sometimes with pink streaks.

## CHEMICAL TESTS

The pear and quince roots were sliced slightly and treated with a few drops of different chemicals. The chemicals that proved helpful in identification are given in Table I along with their color reactions.

TABLE I—COLORS PRODUCED BY VARIOUS CHEMICALS ON THE INNER BARK OF PEAR AND QUINCE ROOTS

Chemical	Color of Inner Bark	
	Quince Root	Pear Root
Ammonium hydroxide 5 per cent	Deeper white	Deep creamy
Ammonium hydroxide (Concentrated)	Creamy	Light yellow
Ferric chloride 60 per cent	Dark greenish brown	Darkens lightly
Sodium hydroxide (Concentrated)	Ochraceous-Salmon* turns Vinea- ceous-Tawny after some time	Lemon Yellow* turns Xanthine orange after some time

\*Colors from Ridgeways Standards and Nomenclature.

Of these four chemicals, sodium hydroxide gave the best color distinction and is therefore preferred.

<sup>1</sup>Government of India student.

The author wishes to acknowledge the cooperation of Dr. W. H. Upshall, Vineland Station, Dr. J. S. Shoemaker and Dr. J. H. L. Truscott of the Department of Horticulture, Ontario Agricultural College, Guelph.



## Varietal Differences in the Calcium, Magnesium, Potassium, and Total Phosphorus Content in Pinnae of Date Palms

By A. R. C. HAAS, *University of California Citrus Experiment Station, Riverside, Calif.*

IN previous reports (2, 3), it was pointed out that the dry matter of the pinnae of the Deglet Noor variety when compared with that of the pinnae of other date palm varieties grown under the same environmental conditions, contains relatively small amounts of chlorine but may contain large amounts of water-soluble boron. It appeared desirable to determine the content of other constituents as well as those already reported.

Only the oldest healthy leaf (lowermost leaf) was collected from the date palms of the Mecca plots<sup>1</sup> in the Coachella Valley. All of the pinnae from a typical leaf furnished abundant material. The pinnae were washed in running distilled water and wiped dry. After being cut into pieces 1 to 2 inches in length, the pinnae were dried in large paper bags in a well-ventilated oven maintained at 65 degrees C. When dry they were finely ground in a large Wiley mill. The powder was placed in envelopes made by folding heavy brown paper and these were inserted into heavy brown paper bags bearing the desired information regarding the sample. The samples were then stored in an oven maintained at 50 degrees C until duplicate aliquots were weighed.

Calcium and magnesium were each determined after double precipitation: the former, as the oxalate, was titrated with permanganate, whereas the latter was weighed as the pyrophosphate. The samples for calcium and magnesium determination were first heated gently at low heat and when cool, the ash was leached with distilled water and the filter paper was returned to the dish for further incineration. Dilute HCl was used to dissolve the white ash. Potassium was determined as the chloroplatinate on samples to which dilute H<sub>2</sub>SO<sub>4</sub> was added prior to the drying and incineration of the samples. The ash was leached with distilled water as in the case of calcium and magnesium between incinerations and dilute HCl was used to dissolve the white ash prior to filtration and evaporation to dryness. Total phosphorus was determined by the stannous chloride-molybdic acid colorimetric method and by the use of a Fisher Electrophotometer. A heavy glass rod was of considerable assistance in pulverizing the puffy ash during the repeated incinerations with magnesium nitrate. Dilute nitric acid was used to dissolve the ash before the filtration and the bringing of the solution to a known volume.

After obtaining the results of closely agreeing duplicate samples, the data were placed in descending order of magnitude, for it was then

<sup>1</sup>These leaves were collected through the kindness and assistance of Dr. Donald E. Bliss of the Division of Plant Pathology, University of California, Citrus Experiment Station, Riverside, California.

more clearly evident as to the effect that the date palm varieties have upon the accumulation of the various constituents of the pinnae.

Table I presents data for the pinnae of 15 different date palm varieties, each of which were growing under similar environmental conditions, with no rootstock to deal with, since these palms are grown from vegetative offshoots. The dry matter of the pinnae in the table show a wide range of content of the different constituents according to the palm variety.

TABLE I—INORGANIC COMPOSITION OF PINNAE OF OLDEST HEALTHY LEAVES COLLECTED DECEMBER 30, 1943 FROM DATE PALM VARIETIES GROWN ON THE MECCA PLOTS IN THE COACHELLA VALLEY OF SOUTHERN CALIFORNIA

Variety	Row	Palm	Content in Dry Matter	Variety	Row	Palm	Content in Dry Matter
<i>Calcium (Per Cent in Dry Matter)</i>				<i>Magnesium (Per Cent in Dry Matter)</i>			
Theory.....	11	5	1.118	Tazizoot.....	16	5	0.244
Zahidi.....	9	5	1.009	Khadrawy.....	13	4	0.235
Deglet Noor.....	12	4	0.873	Barhee.....	10	12	0.218
Dayri.....	15	6	0.812	Kustawy.....	16	10	0.190
Khadrawy.....	13	4	0.781	Zahidi.....	9	5	0.187
Hellali.....	14	12	0.770	Hayany.....	13	12	0.176
Hayany.....	13	12	0.734	Medjool.....	10	11	0.175
Kustawy.....	16	10	0.659	Sayer.....	15	4	0.163
Tazizoot.....	16	5	0.628	Dayri.....	15	6	0.154
Barhee.....	10	12	0.618	Deglet Noor.....	12	4	0.145
Maktoom.....	15	12	0.615	Rhars.....	12	12	0.141
Saidy.....	10	5	0.576	Theory.....	11	5	0.141
Medjool.....	10	11	0.554	Saidy.....	10	5	0.070
Sayer.....	15	4	0.488	Hellali.....	14	12	0.068
Rhars.....	12	12	0.295	Maktoom.....	15	12	0.051
<i>Potassium (Per Cent in Dry Matter)</i>				<i>Total Phosphorus (Ppm in Dry Matter)</i>			
Saidy.....	10	5	0.776	Saidy.....	10	5	1,860
Medjool.....	10	11	0.693	Hayany.....	13	12	960
Sayer.....	15	4	0.692	Theory.....	11	5	940
Rhars.....	12	12	0.670	Tazizoot.....	16	5	870
Kustawy.....	16	10	0.547	Kustawy.....	16	10	870
Tazizoot.....	16	5	0.543	Khadrawy.....	13	4	820
Hayany.....	13	12	0.507	Dayri.....	15	6	760
Hellali.....	14	12	0.499	Hellali.....	14	12	720
Barhee.....	10	12	0.435	Barhee.....	10	12	710
Dayri.....	15	6	0.401	Medjool.....	10	11	650
Theory.....	11	5	0.345	Sayer.....	15	4	640
Zahidi.....	9	5	0.341	Zahidi.....	9	5	630
Maktoom.....	15	12	0.339	Rhars.....	12	12	610
Khadrawy.....	13	4	0.325	Maktoom.....	15	12	600
Deglet Noor.....	12	4	0.232	Deglet Noor.....	12	4	600

Deglet Noor being one of the principal commercial varieties grown in the Coachella Valley is of particular interest. The pinnae of this variety contain large concentrations of calcium, rather low amounts of magnesium and the lowest concentrations of potassium and total phosphorus of any in the entire list of varieties tested. Pinnae of the Khadrawy variety also were very low in potassium content and rather high in calcium, magnesium and total phosphorus. Since the pinnae were taken from the oldest (lowermost) healthy leaf, the low potassium content may be considered an indication that the Deglet Noor palm utilizes the potassium to such an extent as to greatly reduce the residues in the tissues before actual death of the pinnae.

Several varieties of date palms are subject in varying degrees to the "decline-disease" (1). It is known that an adequate nitrogen fertilization practice is essential. The data would suggest possibly the

increasing of the supply or availability of potassium, if not phosphorus, in these soils and the lowering of the calcium absorption.

#### SUMMARY

Data are presented for the calcium, magnesium, potassium, and total phosphorus content of the pinnae of 15 varieties of date palms growing under the same environmental conditions in the Coachella Valley in southern California. The data show a wide range of content of the different constituents according to the palm variety.

The pinnae of the most mature and healthy leaf of Deglet Noor, one of the chief commercial palm varieties, were found to contain large concentrations of calcium, relatively low amounts of magnesium and the lowest concentrations of potassium and total phosphorus found in the pinnae of any of the fifteen palm varieties tested. The data may be suggestive of the need of a greater supply or availability of potassium, if not phosphorus, in these soils and a lowering of the calcium accumulation in pinnae.

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## Toxicity of Peach Roots

By LEON HAVIS and ANNA L. GILKESON, *U. S. Plant Industry Station, Beltsville, Md.*

THE frequent difficulty in obtaining satisfactory growth of peach trees after replanting old peach sites to peaches has been variously explained. One common explanation of this difficulty is that some toxic material produced by the roots of the previous trees is injurious to the replanted trees. The reports of Massey (3) and Strong (8) on walnuts, Schreiner and Reed (6, 7) on wheat, Proebsting and Gilmore (5) on peaches, Benedict (1) and also Myers and Anderson (4) on brome grass, and Bonner and Galston (2) on guayule, all strongly suggest the possibility of toxic action as an explanation. The experiment reported here was set up to determine the effect of additions of peach root bark, whole peach roots, and water-soluble peach-root leachate on young peach trees that were well supplied with all nutrients known to be necessary for vigorous tree growth.

The experiment was conducted during the early spring and summer of 1945 and 1946. The trees used in 1945 were selected 1-year Lovell seedlings budded to Elberta the previous August and cut back to the bud when planted. In 1946 small (2- to 3-foot) June-budded Elberta trees on Lovell stocks, and Elberta seedlings 4 inches in height were used. The 1-year trees were cut back to a single bud. The trees were grown in sand in 3-gallon earthenware crocks connected at the bottoms with 18-liter bottles of nutrient solution. The nutrient solution supplied was composed of approximately 100 parts per million nitrogen, 18 parts per million phosphorus, 32 parts per million potassium, 64 parts per million calcium, 39 parts per million magnesium, and other elements in quantities that have previously been found satisfactory for vigorous growth of young peach trees. The nutrient solutions were maintained in 18-liter carboys, each of which supplied three crocks containing one tree each. The nutrient solution, together with any leachate from the additional roots or bark, was pumped into the crocks three times each day. The solutions were replenished to approximately the original concentration of elements and full volume every 2 weeks. In order to continue to flush the crocks with the root percolate, whatever remained of the old solutions at the time of replenishment was not discarded during the 7-month period of the test each year.

The materials added to the sand medium consisted of (a) peach root bark that was dried at 80 degrees F and ground to pass a 20-mesh screen; (b) root bark frozen in carbon dioxide and similarly ground; (c) whole small fresh roots frozen in carbon dioxide to permit their being ground; and (d) whole fresh roots of various sizes cut into pieces not over  $\frac{3}{4}$  inch long. For most treatments there was a total of six replicates during each of the 2 years.

The principal treatments included in the test are given in terms of the material added to the sand in each crock:

1. 24 grams of dried and ground peach root bark

2. 48 grams of dried and ground peach root bark
3. 300 grams of dried and ground peach root bark
4. 200 grams of fresh (not dried) and ground peach root bark (frozen)
5. 300 grams of fresh (not dried) and ground peach root bark (frozen)
6. 270 grams of fresh (not dried) and ground whole small roots (frozen)
7. 400 grams of chopped whole peach roots
8. Control: neither peach roots nor peach bark added

During the course of the experiments, which extended over the 7-month period from February to August, inclusive, the peach trees grew very well under all treatments during both years of the tests. The average length of all the new wood produced by each tree in 1945 was 946 centimeters. The average increase in total fresh weight per tree that year was 456 grams. During 1946 in the test where small 1-year trees were cut back to one bud, the average weight increase per tree was 451 grams. The 5-inch seedling peach trees used in 1946 grew equally well in sand with the root materials added and in the controls throughout most of the test period. Those growing in the crocks with the roots or bark added, however, grew even more vigorously than the controls during approximately the last 2 months of the 7-month period.

Throughout these tests there was no evidence that there is any "toxic" substance in peach roots or peach leachate that adversely affects the growth of young peach trees in high-nutrient sand cultures. These results are not in agreement with those of Proebsting and Gilmore (5), who found evidence of toxicity in peach root bark. A larger amount of root bark was used in the studies reported here; also the leachate from the root bark was forced through the sand medium three times each day for several months. In fact, new roots of the trees planted in the crocks to which chopped roots had been added actually penetrated well into the bark and along the cambial zone of the old roots without apparent injury to themselves. There are many cases of failure when replanting peaches in the orchard which seem difficult to explain on the basis of soil nutrients. It is possible that the results obtained may not be directly applicable to all orchard soils, but it is additional information on this problem on which we need still more research, since it is becoming more and more serious to peach growers in many areas.

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## The Effect of Three Factorial Levels of Nitrogen and Phosphorus on the Growth and Composition of *Cinchona Ledgeriana*

By ARNAUD J. LOUSTALOT and HAROLD F. WINTERS,  
*U. S. Department of Agriculture, Mayaguez, P. R.*

### ABSTRACT

This material will be published in full in *Plant Physiology*.

**C**INCHONA LEDGERIANA seedlings were grown in sand culture at three levels of nitrogen (3, 18, and 81 parts per million) and three levels of phosphorus (0, 5, and 25 parts per million) in factorial combination.

The low level of nitrogen had a marked depressing effect on the growth of the seedlings, but there was no statistically significant difference in the growth of plants receiving 18 and 81 parts per million of nitrogen.

The high level of phosphorus greatly depressed growth of plants with the low nitrogen supply and to a lesser extent those supplied with a medium nitrogen level. On the other hand growth of the high nitrogen plants was directly correlated with phosphorus level.

Roots and stems of plants grown at the high nitrogen level contained higher amounts of total alkaloid and quinine sulfate than did those of plants grown at the lower nitrogen levels.

There was no consistent effect of phosphorus on the quinine content of the plants in the various treatments, but there was a tendency for total alkaloids to be higher in plants with a high phosphorus level.

The nitrogen content of the leaves varied directly with the nitrogen level at which the plants were grown. At all nitrogen levels the nitrogen content of the leaves was inversely correlated with the phosphorus supply. Thus, at the low nitrogen level the high phosphorus concentration accentuated nitrogen deficiency.

The leaves of plants grown in the low and medium nitrogen levels contained increased percentages of calcium and phosphorus as the phosphorus supply increased but the amounts of nitrogen, potassium, and magnesium in these plants decreased.

The results of this experiment indicate that growth of young cinchona trees may be limited under certain conditions if the phosphorus concentration is too high. They also indicate that the phosphorus requirement of cinchona is relatively low and that for optimum growth the phosphorus must be available in the proper proportion to nitrogen and possibly other mineral elements.

# Investigations on Thinning of Peaches by Means of Caustic and "Hormone" Sprays<sup>1</sup>

By A. E. MURNEEK and A. D. HIBBARD, *University of Missouri, Columbia, Mo.*

**D**UE to the prevailing high cost of labor and the necessity of thinning peaches to secure a desirable size and quality, there is a continuing interest to devise a more economical procedure for this practice. We have considered both the relatively new chemical and physical means of thinning this fruit. A preliminary report of our investigations, giving the results for 1944, has been published (2). The present paper deals with some spraying tests conducted in 1945 and 1946 in the southeastern peach growing region in Missouri.

## THE 1945 TESTS

Elgetol (sodium salt of dinitro-ortho-cresol) having given desirable results in the preceding year, attempts were made to study its use further in 1945 together with the possible value of naphthalene acetic acid (NA) for fruit thinning (1). Unfortunately, because of the distance (300 miles) of the experimental orchard from Columbia, and the extremely hot weather, it was not possible to apply the sprays until almost 100 per cent of petals were off (about 3 to 4 days past full bloom). Still, it was thought of interest to see what effect these sprays might have when used so late. Vigorous Elberta trees were sprayed respectively with Elgetol at concentrations of .125 per cent, .25 per cent and .5 per cent and with sodium salt of naphthaleneacetic acid (commercial "preharvest spray" material) at 5, 10 and 20 parts per million.

The results showed that in no instance was the fruit thinned sufficiently excepting when .5 per cent of Elgetol was used. Even in this case most of the trees had a 25 to 75 per cent overload of fruit. While the 1945 test, therefore, must be considered negative, it should serve as an example of the importance of timely application of such sprays and the difficulty in timing which growers may experience during hot weather in the blooming period.

## THE 1946 TESTS

The season was far more favorable than in the preceding year for such an investigation. The same Elberta trees, now 9 years old, of moderate vigor and bloom because of a very heavy crop in 1945, were used for this purpose; also a block of mixed varieties of heavily blooming uniformly vigorous trees of the same age, planted in replicated rows. All of them had been pruned moderately, but had received heavy applications of a nitrogenous fertilizer.

Warm weather prevailed up to the date of experimental spraying, when the Elberta trees were in full bloom and there had been at least 2 good days for pollination and fruit setting. Trees in the mixed varie-

<sup>1</sup>Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station, Journal Series No. 1044.

ty block had 75 to 100 per cent flowers open when sprayed, with, of course, proportionally fewer flowers pollinated and set. Cool to cold weather prevailed on the day of experimental treatment.

The procedure of spraying and recording of results was the same as given in a previous report (2). All trees that were not sufficiently spray thinned received additional hand thinning at the usual time. The size of the Elberta peaches sprayed with Elgetol, in terms of number of fruit per bushel, was determined when harvested.

The results, presented in Table I, show that these Elberta trees, sprayed 2 days after good pollination weather, required a concentration of .31 per cent ( $2\frac{1}{2}$  pints) or slightly more of Elgetol to thin the

TABLE I—PEACH THINNING EXPERIMENTS, CAMPBELL, MISSOURI  
(1946, ELBERTA)

No. of Trees	Concentration of Spray (Per Cent)	Flowers Set (Per Cent)	Remarks	Per Cent Flowers Set After Hand Thinning	No. Fruit Per Bushel (At Harvest Time)
<i>1. Elgetol Sprays</i>					
8	0.375	4.6	Thinned too much	4.5	140
8	0.31	20.1	Not quite enough	12.6	194
8	0.25	30.1	Not enough	18.7	211
8	0.125	25.2	Not enough	19.3	226
<i>2. Preharvest Sprays</i>					
(Parts Per Million)					
8	40	44.3	Approximately 5 per cent fruit not yet dropped	23.3	—
8	20	35.3	naturally, these included in count	20.2	—
8	10	42.4		20.1	—
7	5	47.0		23.6	—
<i>3. Controls</i>					
8	No spray	33.2	Set too heavy	22.7	225

crop to a desirable extent. This was accomplished by a reduction in the percentage of flowers that set fruit from 33 per cent (controls) to about 20 per cent. As a result of "flower thinning" with Elgetol the size of fruit was increased from 225 to approximately 190 per bushel. The results are in quite close agreement with those obtained in 1944 on the same trees, when Elgetol of .25 to .5 per cent thinned about right peaches.

Naphthaleneacetic acid (NA) at concentrations of 5 to 40 parts per million, instead of thinning the crop, actually increased the fruit set over the controls (Table I). It is probable, though, that it resulted merely in an unnatural delay in abscission of the young fruit. There is a possible indication that with increasing concentration, within limits of 5 to 20 ppm, there was a reduced stimulation of fruit setting.

The same concentration (.31 per cent) of Elgetol thinned to a satisfactory extent the heavily blooming mixed varieties of peaches, the percentage of flowers setting fruit being reduced from 26.4 per cent (controls) to 7.6 per cent (Table II). The preharvest spray material, at a strength above 5 ppm, likewise reduced the set, though insufficiently—from 36 per cent on controls to about 27 to 32 per cent on sprayed trees. A possibly interesting feature of the effects of pre-



TABLE II—PEACH THINNING EXPERIMENTS, CAMPBELL, MISSOURI, 1946—MIXED VARIETIES

No. of Trees	Concentration of Spray (Per Cent)	Per Cent Flowers Set	Remarks	Per Cent Flowers Set After Hand Thinning
<i>Salberta, Halehaven, Elberta, Golden Jubilee, Frank, Mikado, South-Haven</i>				
<i>1. Elgetol Sprays</i>				
13	0.375	4.4	Thinned too much	—
15	0.31	7.6	Thinned just right	—
15	0.25	16.7	Not quite enough	8.4
13	0.125	22.3	Not enough	8.3
<i>2. Controls</i>				
14	No spray	26.4	Set too heavy	7.7
<i>Mikado, Golden Jubilee, Halehaven, South-Haven, Elberta, Salberta, Frank, Early Elberta</i>				
<i>1. Preharvest Sprays</i>				
(Parts Per Million)				
14	40	27.4	Not thinned enough	10.3
11	20	29.9	Not thinned enough	10.6
12	10	32.7	Not thinned enough	10.8
14	5	37.4	Not thinned enough	14.2
<i>2. Controls</i>				
15	No spray	36.1	Set too heavy	12.5

harvest sprays (NA) would seem to be that they may either reduce or stimulate fruit setting depending on the time when the application is made in relation to flower development, more specifically to pollination and fertilization. When used on peaches (mixed varieties) at the period when flowers were 75 to 100 per cent open the set was reduced, but when applied after 2 days of good pollination weather (Elberta) it was probably increased.

Note should be taken here of the interesting fact that when preharvest sprays at 30 ppm were applied during warm weather to young Jonathan and Winesap trees 7 to 9 days after full bloom there was a striking reduction in fruit set: Jonathan, controls—42.5 per cent flower clusters set, sprayed—9.5 per cent set; Winesap, controls—19.2 per cent set, sprayed—7.9 per cent set (3). This would seem to indicate a very marked sensitivity of flowers during sexual reproduction and early stage of embryo development to naphthaleneacetic acid and possibly other synthetic plant growth substances. It might be at least one of the reasons for the erratic results that one frequently obtains when growth substances are used to stimulate fruit setting. The timing of application of "hormone" sprays to flowers, for the purpose of thinning the crop, seemingly must be just as close as when Elgetol is used, if not more so.

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## Phosphorus Deficiency of Peach Trees in the Sandhills Area of North Carolina<sup>1</sup>

By OTTO VEERHOFF, *North Carolina Agricultural Experiment Station, Raleigh, N. C.*

SEVERAL studies of the growth and composition of peach trees in nutrient cultures have provided information concerning the effects of sub-optimal concentrations of phosphate in the substrate (1, 2, 3, 12, 13). However, studies with orchard grown trees have usually not revealed phosphorus deficiency nor response to application of phosphate (8, 11). The present report provides what is apparently the first description of acute phosphorus deficiency in a bearing peach orchard. Growth measurements, foliar symptoms, leaf phosphorus contents, and yields of trees receiving no phosphate fertilizer are compared with those of trees receiving the customary amount of phosphate applied to orchards in the Sandhills area.

### PROCEDURE

Trees of the Elberta variety having 12- to 18-inch tops were planted in December, 1940, on land cleared the previous spring from open woods of the typical longleaf pine and scrub-oak association of the southeastern Sandhills. Half of the peach trees were on roots of "Carolina Natural", which had been the customary rootstock of peach trees of this area. The remaining trees were on seedlings of Shalil (P. I. 63850), a nematode resistant rootstock. The two sets of trees were interplanted, three trees on Shalil rootstock and three on Natural rootstock being in each row. Since similar responses to phosphorus deficiency were found for trees on both rootstocks, the trees are considered as one uniform lot, thus providing six trees in each of the five replications for each treatment.

The soil in this experiment was a yellowish sand underlain with sandy clay at about 4 feet. This type of soil, which is classified as Norfolk sand, is found in the majority of the commercial peach orchards of North Carolina. The virgin soil is very low in fertility, both mineral nutrients and organic matter being at low levels, and the total base exchange capacity is often less than three milli-equivalents per 100 grams. Samples of top soil from the plots that had never received phosphate fertilizer, when extracted with twentieth normal hydrochloric acid, showed less than 5 pounds per acre of available  $P_2O_5$ . The amount in the subsoil was still lower. The soil, which has never been limed, has shown no important change in acidity since the land was cleared. The pH ranged from 5.0 to 5.4. Soil moisture at field capacity is about 6 per cent and at 2 per cent wilting occurs.

<sup>1</sup>Contribution from the Department of Horticulture, North Carolina Experiment Station. Published with the approval of the Director as Paper No. 256 of the Journal Series.

Analyses of leaves were made by Miss Eleanor Gibbs with the guidance of Dr. Ivan D. Jones of the North Carolina Experiment Station. The author also gratefully acknowledges many soil analyses performed by the North Carolina Soil Testing Laboratory, under the direction of Dr. Ivan E. Miles.

Despite the apparently unfavorable characteristics of such a soil, applications of commercial fertilizers enable it to support many successful orchards.

Two mixed fertilizers were used in this experiment, a "complete" fertilizer for treatment A and a "minus P" fertilizer for treatment B. The latter, which had an 8-0-8 analysis, was prepared by mixing crystalline urea, nitrate of soda, nitrate of potash, sulfate of magnesia, and gypsum. The complete fertilizer for treatment A was prepared with the same materials except that ammonium phosphate replaced the urea as the source of ammonium nitrogen so that the N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O analysis was 8-16-8. Both fertilizers contained 2 per cent MgO, 8 per cent CaO, and 7 per cent sulfur.

Trees in treatment A received 1 pound of the 8-16-8 fertilizer during each of the first three years, 1.5 pounds in the fourth year and 3 pounds during each of the last two years. Additional nitrogen was applied at the rate of  $\frac{1}{10}$  pound of nitrogen per tree the first growing season and increased by  $\frac{1}{10}$  pound each succeeding year. Fertilization of treatment B was the same as that for treatment A, except that the 8-0-8 fertilizer was used instead of the 8-16-8.

## RESULTS

*Tree Growth:*—During the first year the growth of trees in the two treatments appeared to be similar. However, measurements of the trunks showed there was a significant difference between treatments in respect to increase in cross-sectional area. The average increase for treatment B was only 57 per cent of that for treatment A (Table I).

TABLE I—COMPARISONS OF GROWTH OF TRUNKS OF ELBERTA PEACH TREES AT THE SANDHILLS' RESEARCH ORCHARD, EAGLE SPRINGS, N. C.†

Fertilizer Treatment	Annual Increase in Trunk			Cross-Sectional Area (Square Inches)			
	1941	1942	1943	1944	1945	1946	1940 to 1947
A, complete.....	0.27	2.27	2.90	2.90	2.24	2.31	12.92
B, minus P.....	0.14	1.20	1.33	1.22	0.65	0.66	5.23
Difference (A-B).....	0.13*	1.07**	1.57**	1.68**	1.59**	1.65**	7.69**
B as per cent A.....	57	53	46	42	29	29	40

†Statistical analyses of this and following tables were made by the Institute of Statistics of the University of North Carolina.

\*Significant at the 5 per cent level.

\*\*Significant at the 1 per cent level.

For each of the following years the difference between treatments in respect to annual increase in trunk size was highly significant. The relative differences became larger each year. During the fifth year the average increase in trunk size for treatment B was only 29 per cent of that for treatment A. At the end of the six years the average cross-sectional areas of trunks of treatment A was 12.92 square inches, whereas the average for treatment B was only 5.23 square inches. The trees of treatment A when 3 years old had an average

cross sectional trunk area of 5.47 square inches, thus being larger in trunk size than the 6-year-old trees of treatment B.

Top growth was similarly restricted in the absence of phosphate fertilizer. By the end of their fifth growing season, the average spread of the branches of the trees in treatment B was less than one-quarter of that for the other treatment. The difference is illustrated in Fig. 1.



FIG. 1. Normal and phosphorus deficient trees at the Sandhills research orchard, Eagle Springs, North Carolina, August, 1945. Trees on the left show the normal growth made in the plots receiving the complete treatment (8-16-8 fertilizer). The stunted trees on the right are the same age but are in one of the minus P plots (8-0-8 fertilizer). Inferior growth of the summer cover crop in the minus P plots is also evident. Foreground shows cut-over woods similar to that cleared in 1940 for the orchard.

All wood removed from the trees after their fourth, fifth, and sixth growing seasons, was weighed soon after the pruning. The average weights of prunings in Table II are for the "new wood" removed, that is, only those portions of the pruned wood which were formed that season were included. The average value for treatment B was only one-quarter that for treatment A.

Length and weight measurements made of samples of terminals produced during 1944 and 1946 showed that the omission of phosphate resulted in formation of terminals that were shorter and lighter in weight. The average shoot of trees in treatment B was only half as long and one-third as heavy as that for treatment A (Table II). The short length of the terminals in treatment B was very noticeable and gave the trees a "stubby" habit of growth similar to that of very old trees.

In 1944 an average of eight flower buds per terminal was found in samples from treatment A but only two per terminal for trees of treatment B. In that year fewer flower buds were produced in the absence of phosphate not only because the growth of terminals was restricted but also because a higher proportion of the nodes carried only vegetative buds or no buds at all. In 1946 nodes carrying no buds were found in large numbers in both treatments.

TABLE II—COMPARISONS OF GROWTH AND FLOWER BUD PRODUCTION OF ELBERTA PEACH TREES

Fertilizer Treatment	Terminal Shoot Averages†						Average Weight of Prunings (Fresh Weight of Wood in Pounds)			
	Length (Inches)		Weight (Grams)		Flower Buds (No)					
	1944	1946	1944	1946	1944	1946	1944	1945	1946	Total
A, complete	19.95	21.65	11.92	15.36	7.96	15.58	9.86	6.14	3.84	19.84
B, minus P	10.26	10.45	4.16	5.42	2.02	8.36	2.98	0.90	1.02	4.90
Difference (A-B)**	9.69**	11.20**	7.76**	9.94**	5.94**	7.22**	6.88**	5.24**	2.82**	14.94**
B as per cent of A	52	48	35	35	25	54	40	15	27	25

†Averages of 10 samples from five replications.

\*\*Significant at the 1 per cent level.

*Foliar Symptoms:*—Some foliar symptoms suggestive of a phosphate deficiency were evident in treatment B during the latter part of the second summer. However, striking differences between the foliage in the two treatments were not apparent until the third year. As the summer of that year progressed, the leaves of treatment B became bronzed or tanned in appearance and developed a leathery texture. Later in the fall the undersides of leaves that were more exposed to the sun showed a distinct reddening of the veins and interveinal areas. As the trees became older, this red coloring was observed earlier in the season and was more intense. The petioles were often abnormally red with much of the surface of the young branches similarly colored. The dentation at the edge of the leaves became a dark crimson to form a narrow, distinct margin that was most evident when the leaves were viewed edgewise.

This development of a bronzed condition of the foliage of treatment B is similar to that described for phosphorus deficiency of peach trees in nutrient cultures (1, 2, 3, 11, 12). The leathery texture of the leaves has also been noted for trees deprived of phosphate (13, 10). The red coloration of leaves, petioles, and branches which was observed in the present experiment is the characteristic response of many kinds of plants to phosphate deficiency.

The shape and size of most of the leaves in treatment B appeared to be normal. No long, narrow leaves were observed similar to those described for trees in phosphate deficient cultures (1, 2, 3, 12). No increase in leaf size as reported by others (10, 13) was observed in this experiment. Although visual comparisons indicated no difference between treatments with respect to size of the leaves formed early in the summer, those from treatment B were 9 per cent smaller on the basis of fresh weights. However, leaves which developed late in the season in treatment B were unusually small, the last few leaves on a terminal often being less than half normal size. Reduction in leaf size due to phosphate deficiency has been reported for peach trees by Wallace (11) and Hoagland and Chandler (5).

Terminal growth of shoots ceased 3 to 6 weeks earlier than normal in treatment B. Near the tips of the shoots the leaves were separated

by such very short internodes as to appear to be arranged in a whorl. The older leaves fell in August, leaving the branches bare except for tufts of these small leaves. These small leaves at the end of a branch were posed perpendicular to its axis in a manner similar to that described by Brown (1).

*Leaf Phosphorus*.—Analyses for leaf phosphorus content, by a method similar to that of Koenig and Johnson (6), were made of samples collected at different time during each growing season after the first year. Leaves at approximately the thirteenth node from the base were selected for sampling. This selection, by providing material of about the same degree of maturity, permits the use of data in Table III not only for comparisons of the effect of treatment, but also for comparisons of the concentration of phosphorus in the leaves at different times in the season.

TABLE III—PHOSPHORUS CONCENTRATIONS IN ELBERTA PEACH LEAVES

Fertilizer Treatment	Month	Leaf Phosphorus (Per Cent of Dry Weight)						Mg P Per Leaf†
		1942	1943	1944	1945	1946	Average	
A, complete.....	May	—	—	0.205	0.216	0.224	0.215	0.486
B, minus P.....	May	—	—	0.160	0.173	0.143	0.159	0.327
Difference (A-B)...	—	—	—	0.045**	0.043**	0.081**	0.056**	0.159**
B as per cent of A...	—	—	—	78	80	64	74	—
A, complete.....	Jul	0.143	0.149	0.149	0.157	0.127	0.145	0.463
B, minus P.....	Jul	0.114	0.127	0.104	0.118	0.092	0.111	0.330
Difference (A-B)...	—	0.029**	0.022**	0.045**	0.039**	0.035**	0.034**	0.133**
B as per cent of A...	—	80	85	70	75	72	77	—
A, complete.....	Aug	0.121	0.119	0.113	0.142	0.115	0.122	0.485
B, minus P.....	Aug	0.089	0.086	0.089	0.119	0.094	0.095	0.364
Difference (A-B)...	—	0.032**	0.032**	0.024**	0.023**	0.021**	0.027**	0.121**
B as per cent of A...	—	74	72	79	84	82	78	—
Average of A+B...	May	—	—	0.182	0.193	0.184	0.186	0.406
Average of A+B...	Jul	0.129	0.138	0.127	0.137	0.110	0.128	0.396
Average of A+B...	Aug	0.105	0.103	0.101	0.130	0.105	0.109	0.424

†Average of all years listed.

\*\*Significant at the 1 per cent level.

Leaves from treatment B had significantly lower concentrations of phosphorus than leaves from treatment A on every sampling date. The average reduction in percentage of leaf phosphorus was .056 per cent in May samples, .034 per cent in July samples and .027 in August samples. However, the relative decreases in phosphorus concentrations were practically the same regardless of season (Table III). As the trees grew older it might be expected that the effect of lack of phosphate would become increasingly evident in the leaf analyses, but, the differences between values for treatments A and B indicate no consistent trend through the five years studied.

The average July value for treatment B, 0.11 per cent, is the same as that found by Cullinan, Scott, and Waugh (2) and by Brown (1) for phosphate deficient trees in nutrient cultures. This low value was found in the present experiment in July, 1942, although visual symptoms of phosphate deficiency were not evident in the leaves until later that year.

The concentration of phosphorus in the dry matter of the leaves showed a significant decrease from May to July for both treatments. The decrease from July to August was also statistically significant for treatment A each year, but decreases in treatment B did not occur during 1945 or 1946. Lilleland and Brown (8) found a significant decrease in the percentages of phosphorus in the dry matter of peach leaves from orchard trees from spring to early summer but only a slight decrease during the summer.

When values in Table III were calculated in terms of milligrams of phosphorus per leaf, the decrease in concentration of leaf phosphorus with advancing season was found to be mainly a result of increased dry matter content of the leaves. The actual amounts of phosphorus per leaf showed no consistent change with advancing season. The average amount of phosphorus per leaf from treatment A was 0.47 milligrams as against 0.34 milligrams for treatment B.

*Fruit Yields and Quality*.—No fruit was harvested from these trees until they were 5 years old. Freezing temperatures in 1943 destroyed all of the fruit, and a frost in 1944 killed most of the flowers. No serious cold damage occurred in either 1945 or 1946 and rainfall was favorable for growth of fruit. Yields for each of these years are compared in Table IV. Size, which was determined mechanically by weight (4), is expressed in the customary manner of minimum diameter. Fruit from treatment A that fell in the large size, "over 2½ inches", had an average weight of .37 pounds and fruit listed as "under 2 inches" had an average weight of .17 pounds. The fruit from treatment B was flattened laterally, the cheeks of the peach failing to enlarge normally. This compressed shape would have placed more of the peaches from treatment B in the small size classes if grading had been done by the customary method of minimum diameters rather than on the basis of weight.

TABLE IV—COMPARISON OF YIELDS, SIZE AND COLOR OF PEACHES

Fertilizer Treatment	Yield Per Tree				Size of Fruit				Color of Skin	
	Weight (Lbs)		No. of Fruit		Per Cent Over 2½ Inches		Per Cent Under 2 Inches		(Per Cent of Surface Red)	
	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946
A, complete.....	32.1	68.2	109	228	21.2	31.5	3.0	6.9	48	30
B, minus P.....	12.5	12.0	49	46	4.6	10.0	27.6	23.9	74	66
Decrease (A-B)	19.6**	56.2**	50**	182**	16.6**	21.5**	—	—	—	—
Increase (B-A)	—	—	—	—	—	—	24.6**	17.0**	26**	33†

\*\*Significant at the 1 per cent level.

†Not analyzed statistically. Estimate of color was made on a composite sample from all replications.

Fruit from treatment B was significantly smaller both in respect to average fruit weight, which was 22 per cent less than that for treatment A, and on the basis of percentage of fruit falling into the different size classes (Table IV). The percentage of peaches in the large grade, (over 2½ inches) was reduced with the omission of phosphate from the fertilizer, and the percentage of peaches in the small grade

was greatly increased. One-fourth of the fruit from treatment B was too small for commercial use as compared with about one-twentieth of the fruit from treatment A.

In 1945 trees of treatment B produced only half as many fruit as trees of treatment A and in 1946 they produced only one-fifth as many fruit as the latter. In these two years treatment B produced 24.5 pounds per tree, whereas the trees receiving phosphate in the fertilizer averaged 100.3 pounds of fruit. In the second year of bearing, treatment A produced twice as much fruit as it did the first bearing year, but yields of treatment B showed no increase.

Fruit of the phosphate deficient trees colored earlier than normal and visual estimates made in 1945 indicated that 26 per cent more of the skin area was covered with red color. This color was not that normally seen in Elbertas but a more bluish hue. Hoagland and Chandler (5) found earlier ripening and higher fruit color for peaches grown without phosphate. The trees in the present experiment also appeared to ripen fruit earlier. The texture and flavor of the fruit was not like that of ripe peaches and they were so unpleasant in taste that they were considered inedible. Longitudinal cracks that often penetrated halfway through the flesh were frequent on these peaches and many were disfigured by gumming.

*Response of Other Plants:*—The effects of phosphate deficiency were evident in the annuals growing in the plots of treatment B (see Fig. 1). Cover crops of rye, oats, and barley were very small and their leaves were a dark reddish color that was most pronounced soon after sprouting. Crabgrass made inferior growth with reddish leaves which assumed a violet color at the time the seeds were maturing. *Crotalaria spectabilis* was also stunted, the leaves being darker than normal with an olive green color. Corn showed the characteristic symptoms of phosphate deficiency at an early stage of growth and some plants tasseled when only 18 inches tall. Tomato leaves also had the purple coloration typical of this deficiency.

The omission of phosphate from the fertilizer applied to treatment B resulted in reduced growth of the cover crops and thus less organic matter was returned to the soil of these plots. However, after six years of the experiment only 0.12 per cent less organic matter was found in topsoil from the no phosphate plots than was found in topsoil from treatment A.

## DISCUSSION

This experiment indicates that the complete omission of phosphate from the fertilizers applied to peach trees on virgin soil of the Sandhills area results in the development of acute phosphorus deficiency. Milder forms of this deficiency have been observed in young commercial orchards of this area where the trees were on newly cleared land and had received only nitrogenous fertilizer. Symptoms of phosphorus deficiency were not seen in bearing orchards. This is probably due to the customary use of complete fertilizers. These older orchards probably have sufficient phosphate since various experiments in this



area have consistently failed to show a beneficial response to applications of additional phosphate.

The results of the present experiment should not be interpreted as evidence that phosphate applications should be increased for orchards of this area, but rather that complete fertilizer may be preferable to one containing no phosphate for young orchards on newly cleared land. Since the nitrogen requirement of a peach tree in this area is very high, at least 1 pound annually, and since the complete fertilizers commonly used in the Sandhills have carried two units of phosphate for each unit of nitrogen, it is evident that during the life of an orchard considerable amounts of phosphate may be applied to the soil. In many orchards a major portion of the phosphate applied may be unnecessary for the nutrition of the trees and uneconomical for the grower.

The probable magnitude of the phosphate requirement of peach trees in this area is indicated by the response of the border row of the experimental orchard to phosphate that was broadcast prior to planting the trees. Less than .10 pound of  $P_2O_5$  per tree was applied in this manner, but this was sufficient to permit normal tree growth for 4 years. A decline in growth was evident by the time the trees were 5 years of age. However, even in the fifth and sixth years the effect of this one application of phosphate was still evident. These trees produced two and a half times as many fruit as treatment B and were only 30 per cent less productive than treatment A. The total phosphate applied during the six years of the experiment was equivalent to 1.5 pounds of  $P_2O_5$  per tree in treatment A, and to 0.1 pound per tree of the border row.

The effectiveness of small amounts of phosphate in Sandhills orchards on newly cleared land is also shown by the study of Scott (10). In that experiment trees receiving a minus-phosphate fertilizer failed to develop severe symptoms of phosphate deficiency and did not show any serious reduction in vigor. However, the minus-phosphate fertilizer contained some cottonseed meal. This nitrogen carrier has recently been found to supply a considerable amount of the phosphate required by strawberries on newly cleared land (9). Probably the use of cottonseed meal fertilizer would also delay the development of phosphorus deficiency in peach trees. The amount of phosphate annually supplied in this manner by Scott's fertilizer was equivalent to less than 0.05 pound of  $P_2O_5$  per tree, yet the trees produced 88 per cent as much fruit as those given a complete fertilizer supplying 0.40 pounds of  $P_2O_5$ .

In the light of the foregoing considerations it would appear that the customary applications of phosphate at the rate of approximately 1 pound of  $P_2O_5$  per tree annually is much in excess of the amounts necessary for peach trees in the Sandhills area. Smoothed graphs of data from the present work and the South Carolina experiment (10) indicated that 0.1 pound of  $P_2O_5$  per year was sufficient for a tree in this area during its first six years of growth. As the "border-line" of adequate phosphate supply is approached the decrease in fruit size probably will indicate the deficiency more clearly than the decrease in

number of fruit (see Table IV). Leaf analyses may also serve in determining whether this element is an important limiting factor. In this experiment values as low as 0.09 per cent phosphorus for the dry matter of late summer leaves were associated with a serious shortage of phosphate in the tree.

### SUMMARY

Elberta peach trees that were set on newly cleared land and had received no phosphate fertilizer have developed acute symptoms of phosphorus deficiency.

At the end of the first year, trunks of trees receiving an 8-0-8 fertilizer were significantly smaller than those of trees receiving an 8-16-8 fertilizer. The depressing effect of insufficient phosphate upon growth of trunks and extension of branches became more pronounced each growing season. The trees when 6 years of age had not attained the size of 3-year-old trees receiving complete fertilizer.

Fruit production in the fifth and sixth years was reduced 75 per cent. The quality of the fruit was also inferior, being small and unpleasing in flavor and appearance.

Foliage was dark green, becoming bronzed in late summer with reddened veins and petioles. Defoliation was premature, only the small terminal leaves remaining in September.

Dried samples of leaves averaged 0.10 per cent phosphorus during the summer, as compared with 0.13 per cent P for samples from trees receiving complete fertilizer.

Very small amounts of phosphate fertilizer were effective in reducing the intensity of the phosphorus deficiency. The customary use of complete fertilizers probably supplies phosphate in excess of the requirements of the peach trees in the Sandhills.

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## Influence of High, Medium, and Low Soil Moisture on Growth and Alkaloid Content of *Cinchona Ledgeriana*

By ARNAUD J. LOUSTALOT, HAROLD F. WINTERS, and NORMAN F. CHILDERS, *U. S. Department of Agriculture, Mayaguez, P. R.*

### ABSTRACT

This material will be published in full in *Plant Physiology*.

SEEDLINGS of *Cinchona ledgeriana* were grown in greenhouse chambers under high-, medium-, and low-soil-moisture conditions at Mayaguez, Puerto Rico. The temperature was automatically controlled and the humidity was maintained relatively high. Leaves of seedlings grown under high-soil-moisture conditions developed necrotic spots between the veins and many of them eventually yellowed and abscised. This disorder, which resembles magnesium deficiency or manganese toxicity in other plants, has been commonly observed in the station field plantings at Toro Negro National Forest, Puerto Rico. Seedlings grown under low-soil-moisture conditions were significantly shorter with a lower top-root ratio and less fresh and dry weight, but a higher percentage dry matter than seedlings grown under either medium- or high-soil-moisture conditions. Total alkaloid and quinine sulfate in roots of seedlings grown in medium and high soil moisture were significantly higher than those in roots of seedlings grown in low soil moisture. Percentages of ash, calcium, and magnesium were highest in plants grown in low soil moisture and lowest in plants grown in high soil moisture. The nitrogen, phosphorus, and potassium contents, however, were significantly the least in plants grown in low soil moisture.

# Blossom Bud Differentiation and Embryo Development in *Prunus Mahaleb*

By ALBERT H. TILLSON, *U. S. Department of Agriculture,  
Glenn Dale, Md.*

THE Mahaleb cherry (*Prunus Mahaleb* L.) exhibits strain differences great enough to suggest effects on edible cherries grafted on it (2, 3). The frequency of self-unfruitfulness (3) and of low seed yields in this species warrants study of its pollination processes, if elite strains of seedlings are to be produced. As a part of this study, investigation of blossom initiation and development has been undertaken. Since circumstances preclude completion of this phase of the study, the present paper sets forth the results obtained, which seem to establish a norm, though they do not reveal the possible variations.

Lateral buds were collected at intervals during the growing seasons of the years 1939 to 1942 and in 1946 from the various lots of Mahaleb cherries grown at the United States Plant Introduction Garden, Glenn Dale, Maryland. The collections used in 1939 to 1942 were from commercial "American Mahaleb"; those of 1946 were from the "Dutch" and "Russian" lines reported by Joley (3). Through each series, collections were made from the same trees.

Table I gives the dates of initiation of the various floral organs for the seasons during which this study was in progress. In the following discussion the dates given are for the 1940-1941 season.

TABLE I—BLOSSOM BUD DIFFERENTIATION OF *Prunus Mahaleb* L.

	1939-40		1940-41	1941-42	1946-47	
	Spurs	Long Twigs			Russian	Dutch
Initiation of floral bud.....	—	Sep 5	Jul 29	Aug 26	—	Jul 31
Initiation of sepal primordia.....	—	Sep 5	Sep 3	—	—	—
Initiation of petal primordia.....	—	Oct 9	Sep 3	Sep 22	—	Sep 5
Initiation of stamen primordia.....	—	Oct 9	Sep 16	Oct 14	—	Sep 19
Initiation of carpel primordia.....	Oct 9	Oct 16	Sep 16	Nov 10	Sep 5	Oct 2
Sporogenous cells in anther.....	—	Feb 20	Oct 28	Jan 5	Oct 14	Nov 20
Pollen mother cells.....	—	Mar 5	Nov 4	Mar 24	Nov 20	—
Carpel edges touching.....	—	Apr 9	Apr 3	Apr 11	—	—
Initiation of ovule.....	—	Apr 16	Apr 9	Apr 11	—	—
Tetrads present.....	Apr 16	Apr 26	Apr 14	Apr 11	—	—
Pollen present.....	Apr 23	Apr 29	Apr 14	Apr 11	—	—
Integuments inclose nucellus.....	Apr 29	May 1	Apr 16	Apr 11	—	—
Megaspores present.....	May 1	May 6	Apr 16	Apr 11	—	—
Embryo sac 8-nucleate.....	May 1	May 7	Apr 19	—	—	—
Anthesis.....	May 7	May 10	Apr 21	Apr 29	—	—

In buds collected on July 29 the increased height of the apical meristem gives the first evidence of transition from the vegetative to the floral type of apex. The lateral protuberances from the base of the floral apex which appear at this time are the first of six floral bud primordia formed in each winter bud. During the following month the apex continues to grow in length and breadth and additional floral bud primordia are initiated in acropetal succession (Fig. 1, 1). By August 12 a subtending bract has developed from each of the basal primordia. The earliest indication of the formation of sepal primordia is in buds

collected September 3. At this time the five sepal primordia appear as slight elevated masses at the outermost rim of the flower bud primordium (Fig. 1, 2). One week later an inner petal whorl of five protuberances arises, alternating with the sepals (Fig. 1, 3). After the initiation of the sepals the continuing cell division in and adjacent to the sepal bases results in the increased length and width of the sepals. This growth is at first in a horizontal direction, but soon a vertical curvature develops, and the sepals and petals are found attached at the top of a tube, which Brooks (1) has shown to be floral and not toral in origin in the almond.

About the middle of September, in rapid succession three whorls of stamens appear on the base of the floral tube. The first whorl differentiates opposite the calyx lobes, the second opposite the petal lobes, and finally a whorl of 10 stamen primordia arises alternating with the lobes of the perianth. At this time also appears the first indication of carpel initiation. The carpel begins by the rounding up of the apex into a convex surface with the highest point, which becomes the dorsal side, slightly off center. Growth of the apex continues vertically from the dorsal edge and in two ridges running toward the ventral side, so that there results a slope from the top of the dorsal side to the bottom of the ventral side, with the dorsal margin tending to become perpendicular (Fig. 1, 4). By early December the structure, as seen in cross section, has assumed the shape of a horse shoe, the edges of which later are to unite to form the ventral suture.

The sporogenous tissue of the anther is first apparent by the end of October as a layer of more deeply staining, densely cytoplasmic cells. During the first week in November the sporogenous tissue differentiates into pollen mother cells (Fig. 1, 5). At this time several sweet and sour cherry varieties (Schmidt's Bigarreau, Seneca, and Montmorency) growing at the station were examined and found to have pollen mother cells in a stage of development slightly more advanced than those of the Mahaleb. In this condition the buds pass the winter with little change except for the very slow growth in size of the various floral organs.

During the latter part of March the pollen mother cells and their nuclei enlarge greatly (Fig. 1, 6). About April 14 the final stages in the formation of pollen follow one another in rapid succession. In a single floral bud may be found pollen mother cells, tetrads, and pollen. Meanwhile there has been a more rapid swelling of the winter buds and elongation of the floral axes until, with a final surge of growth, about April 14 they burst open the bud scales.

Meanwhile about the first of April the ventral edges of the carpel come together to form the locule. The pistil now enlarges considerably and about April 9 the two ovules originate as protuberances from the ventral margins near the base of the carpel (Fig. 1, 7). Differentiation of the ovules progresses rapidly. Five days after its initiation the ovule tip commences to turn upward toward the style (Fig. 1, 8), and the beginning of the single integument may be seen as a ring of tissue projecting from the base of the ovule (Fig. 1, 9). Two days later the integument almost completely incloses the nucellus (Fig. 1, 10) and

megaspores are present. Growth in the base of the ovary wall gradually elevates the two anatropous ovules so that their point of attachment is about half way to the top of the locule, with their micropyles pointing toward the style. On April 19, 10 days after ovule differentiation was first evident and 2 days before anthesis, mature 8-nucleate embryo sacs are present in the ovules. Pollen grains were mature 7 days prior to anthesis.

During the spring of 1942 a preliminary investigation of embryo development was made. For this study Mahaleb pistils which had been pollinated with pollen from other lots of Mahaleb seedlings were collected at intervals. Fertilization was found to occur about 48 hours after pollination, and the second ovule begins to disintegrate. One day later the zygote and degenerating synergids may be seen at the micropylar end of the embryo sac. The primary endosperm nucleus begins to divide before that of the zygote, and the daughter nuclei move to the periphery where they continue to divide rapidly without wall formation in the thin layer of cytoplasm lining the embryo sac. Meanwhile the embryo sac enlarges greatly, especially in length.

Three days after fertilization (assuming that fertilization takes place 2 days after pollination) the young embryo, now about 26 microns long, may be seen with its basal end attached to the nucellus at the micropylar end of the embryo sac (Fig. 1, 11). Aborted embryos become evident at this time, distinguishable from normal embryos by the shrunken, plasmolysed appearance of their cells and different reaction to stains. Of 13 embryos examined at this stage, 3 were aborted. No evidence of embryo abortion at a later period was found.

The 6-day embryo has increased to 52 microns in length and the endosperm is still coenocytic (Fig. 1, 12). The 10-day embryo is still spherical in shape and about 90 microns in diameter (Fig. 1, 13). About this time the endosperm nuclei become separated by walls. Fourteen days after fertilization the embryo, now a heart-shaped structure about 360 microns long in which vascular differentiation has begun, is surrounded by a layer of cellular endosperm only a few cells thick at the sides but forming a thick fleshy cap opposite the well-developed cotyledons (Fig. 1, 14 and 15). The endosperm never completely fills the ovule, but gradually differentiates toward the chalaza as its inner surface is absorbed by the growing embryo. The mature seed is without endosperm. The 18-day embryo is 516 microns long. About this time the plumule differentiates and the embryo enters a period of very rapid growth. One ovule was found with well-developed endosperm but no trace of an embryo. Thirty days after fertilization the embryo, about 5.5 millimeters long, completely fills the ovule (Fig. 1, 16). The endosperm, except for a small amount in the space around the hypocotyl, has disappeared, and the nucellar tissue has been almost completely absorbed. The cells of the integument are rapidly becoming compressed into a papery layer. In one fruit it was found that both ovules had developed mature embryos. Fifteen days later the seed is mature.

A study of the data given in Table I reveals that there is considerable variation in the time of differentiation. During the 1939-1940

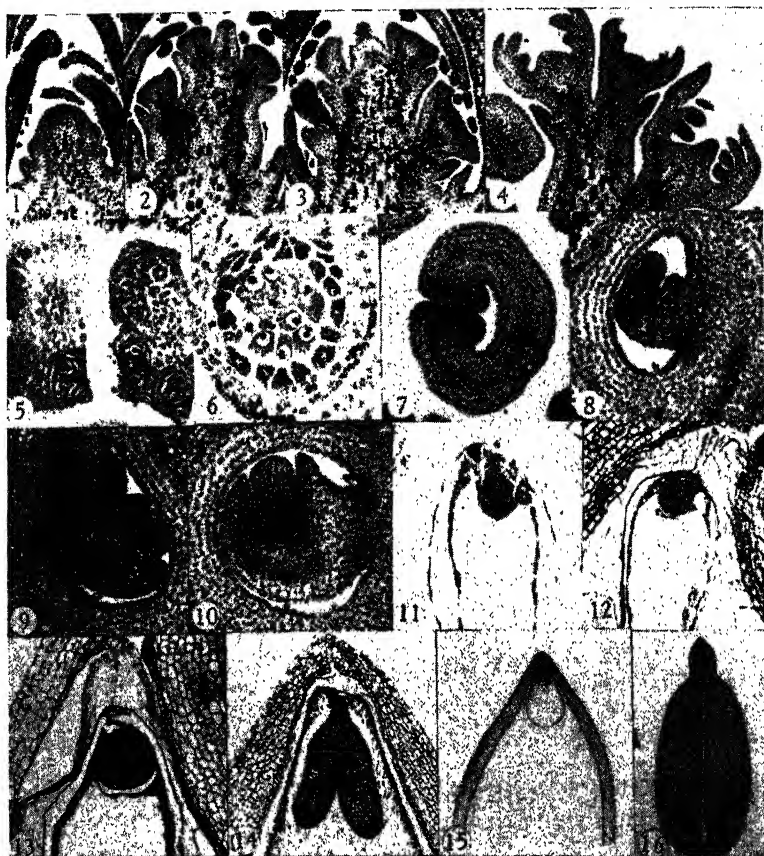


FIG. 1. (1) Longitudinal section of bud (August 12, 1940) showing initiation of floral primordia,  $\times 50$ . (2) Initiation of sepals in the basal blossom primordium (September 3, 1940). Each blossom primordium has a subtending bract,  $\times 50$ . (3) Initiation of petals (September 9, 1940),  $\times 50$ . (4) Early stages of stamen and carpel formation (October 14, 1940),  $\times 50$ . (5) Transverse section of anthers (December 9, 1940) showing pollen mother cells,  $\times 228$ . (6) Pollen mother cells (April 14, 1941) just prior to reduction-division,  $\times 228$ . (7) Transverse section of carpel (April 10, 1941) showing the origin of the two ovules from the ventral margins, which are not yet closely united,  $\times 93$ . (8) Longitudinal section of carpel (April 14, 1941) showing growth of ovule and origin of the integument,  $\times 93$ . (9) Later stage in ovule development (April 15, 1941),  $\times 93$ . (10) Ovule almost entirely inclosed by integuments (April 16, 1941),  $\times 93$ . (11) Embryo 5 days after pollination,  $\times 228$ . (12) Embryo 8 days after pollination,  $\times 93$ ; nuclei of coenocytic endosperm may be seen. (13) Embryo 12 days after pollination,  $\times 93$ . (14) Embryo 16 days after pollination, showing early stage of cotyledon development,  $\times 50$ . (15) Embryo 16 days after pollination showing cellular endosperm,  $\times 8.4$ . (16) Embryo 32 days after pollination, showing the hypocotyl and the plumule between the two thick cotyledons,  $\times 5.6$ .

season, buds on spurs differentiated floral parts 5 to 10 days ahead of buds on long twigs. Position on the tree did not appear to be a factor. Transition from the vegetative to the floral type of apex was first apparent in late July in 1940 and 1946, but in 1939 and 1941 differentiation was delayed until the latter part of August. In the "early" seasons the buds went into the winter with pollen mother cells already differentiated, a condition which various workers have shown to be common in cherries, while in the "late" seasons pollen mother cells were not apparent until March. A more rapid differentiation in early spring almost made up for the delay in development during the preceding fall. During the autumn of 1946 a comparison as to stage of differentiation was made between seedlings originating from Russia and those from Holland. Buds from the Russian seedlings, which Joley (3) had found to be more vigorous than the Dutch seedlings growing in close proximity, were about 1 month ahead of the Dutch seedlings. These variations would seem to warrant a further inquiry into the effect of such factors as weather conditions, soil moisture, nutrient level, vigor and parentage of trees on the floral bud development of Mahaleb seedlings.

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## Stone Cells in *Vaccinium*<sup>1</sup>

By J. A. YARBROUGH, *Meredith College, Raleigh, N. C.* and  
E. B. MORROW, *North Carolina State College, Raleigh, N. C.*

THE occurrence of stone cells in the flesh of the huckleberry (*Gaylussacia resinosa* Torr. & Gray) was recorded by Winton (12) in 1902. Later in treating the fruits of the Ericaceae, Winton (13) describes and figures these cells for *Gaylussacia* but in referring to the mesocarp of *Vaccinium* says: "mesocarp of thin-walled cells, some sclerenchymatized but not, as in huckleberry, stone cells". Winton (12) also recognized a layer of sclerenchymatous cells forming the endocarp in both of these genera as well as in the red and black currants. Eames and McDaniels (5) refer to stone cells as being present in the flesh of the fruit of *Gaylussacia* but do not mention *Vaccinium* in this connection.

Observations by the authors in the summer of 1946 indicated widespread occurrence of stone cells in the flesh of horticultural varieties of *Vaccinium ashei*. Since scant notice has been paid this character in recent horticultural literature on blueberries, it seemed desirable to compare *V. ashei* with other species. Collections were therefore made of the following additional species: *V. altomontanum*, *V. constablaei*, *V. tenellum*, and *V. australe* (horticultural varieties Rubel and Dixi).

### METHODS

Freehand sections of mature fruit preserved in F.A.A. were treated with phloroglucin and HCl (Sass, 10) to determine presence and distribution of lignified cells. Fruit samples were also run into paraffin, sections made at 20 $\mu$  and stained in crystal violet and erythrosin (Johansen, 9). Drawings were made with a camera lucida.

### OBSERVATIONS

The outer epidermis of these fruits consists of a single cell layer without stomata as Eames and McDaniels (5) indicate. In the epidermis, as in the several-layered hypodermis lying beneath, there is a dark purple pigment giving color to the fruit (Fig. 1, A and Fig. 2). In most varieties examined no pigment was present beneath the hypodermis. Notably, however, the two varieties of *Vaccinium australe* (Rubel and Dixi) showed pigment throughout the entire fleshy pericarp.

In all varieties studied the endocarp consists of a single layer of stone cells which are fitted together very tightly (Fig. 1, A and B), and constitutes a lining of the five compound locules. The individual cells of this layer are seen to be much smaller and more elongated than the stone cells lying in the flesh of the mesocarp (compare Fig. 1, B, C and D). They present, however, the same fundamental structure with strongly lignified walls and many simple pits.

The stone cells of the fleshy mesocarp vary somewhat in shape and

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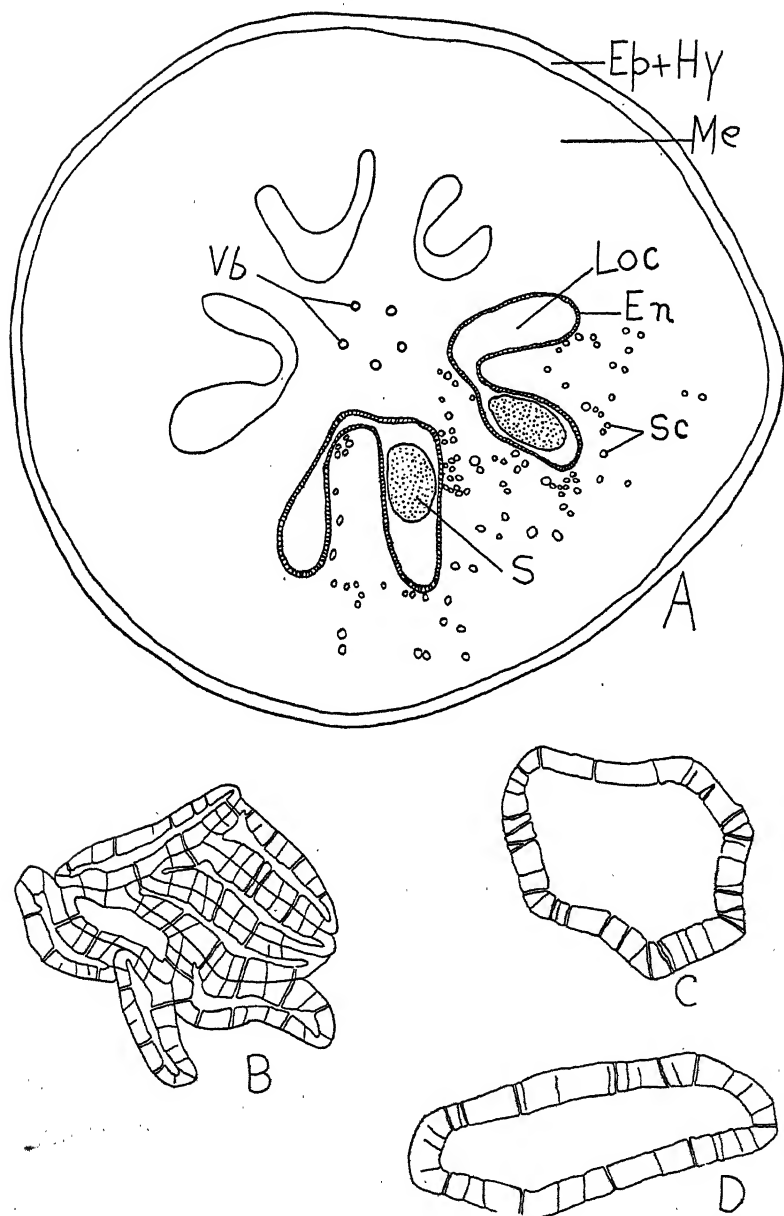


FIG. 1. A, Transverse section of mature fruit of Black Giant (*Vaccinium ashei*) ep + hy, epidermis and hypodermis; me, mesocarp; en, endocarp; loc, locule; s, seed; sc, stone cells; vb, vascular bundles,  $\times 8$ . B, A group of cells comprising the endocarp showing grouping and wall pits as seen in optical section,  $\times 215$ . C and D, Stone cells of the mesocarp as seen in optical section,  $\times 215$ .

size but are larger than those comprising the endocarp. They have a relatively smooth and rounded surface without arms or lateral extensions. When abundant, they may be found in small groups in the mesocarp yet are often seen to occur singly. This is particularly true when they are less abundant as in Dixi and Rubel varieties. In those varieties with most numerous stone cells they may appear to be concentrated in a zone around the locules, although there appear all gradations from this condition to that of only a few such cells which usually appear nearer the epidermis.

As indicated above, a considerable variation in abundance of stone cells was seen in the varieties and species examined. It was noticeable that in varieties of *Vaccinium ashei* these cells were moderately to very abundant; *V. tenellum* showed moderately abundant stone cells and these were mostly of a larger type; and *V. constablaei* and *V. australe*, on the other hand, showed a very low incidence of stone cells. The number in Rubel and Dixi (horticultural varieties of *V. australe*) were lowest of all. Selections from progenies of *V. ashei* by *V. constablaei* showed variation from abundant to very sparsely scattered stone cells. It is significant that of the above varieties and species, those with abundant stone cells also exhibited the character of "grittiness" in a more pronounced fashion and were generally less palatable than those containing few stone cells. This would indicate that stone cells may be the prime factor in causing grittiness in *Vaccinium* fruit.

Seeds in each locule vary much in size and number (Fig. 2). They are covered by a layer of heavily lignified cells, as others have described (Winton, Eames, and McDaniels), and are a second factor contributing to the grittiness of the fruit.

A third structure which may be related to this character, however, is the enlarged, woody placenta (Fig. 2) which in some varieties may be more than twice the size of the largest seeds. Darrow and Camp (4) note this structure as contributing to an unappetizing quality of cooked fruit in several species. This placental tissue is sharply contrasted with adjoining tissue of the fruit by its dark color even in untreated sections. These woody placental "knobs" easily break off in sectioning the ripe fruit. Affinity for safranin and crystal violet stains indicate their lignified character. This placental specialization was seen in all varieties examined but varied significantly in size. Varieties of *Vaccinium ashei* had woody knobs with diameters nearly twice those of similar structures in *V. australe* (Rubel and Dixi). Since those fruits with large placental knobs were generally smaller in size, it would appear that this structure as well as relative abundance of stone cells, and seed number and size, contributes materially to the grittiness of such fruits.

#### DISCUSSION

As indicated by structure and lignin reaction, it is clear that true stone cells occur in the fleshy mesocarp of the varieties of *Vaccinium* spp. examined. While these cells do not occur in such abundance as in *Gaylussacia* (Winton, 12) or in the pear (Crist and Batjer, 3), they correspond to stone cell types as described by Eames and McDaniels (5). From the figures in Winton's paper and the authors' observa-

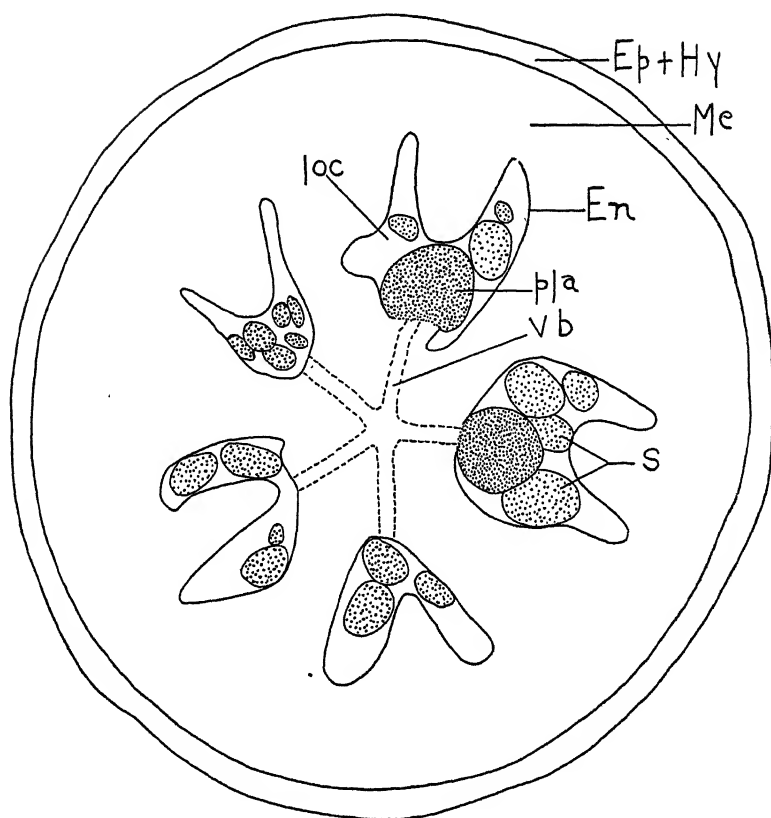


FIG. 2. Transverse section of mature fruit of Myers (*Vaccinium ashei*), ep + hy, epidermis and hypodermis; me, mesocarp; en, endocarp; loc, locule; pla, placenta (lignified "knob"); vb, vascular bundle; s, seeds,  $\times 7.5$ .

tions, it appears that the difference in the lignified cells in the mesocarp of *Gaylussacia* and those of *Vaccinium* is one of quantity or abundance rather than one of quality or structural type. The lower incidence of such stone cells and thus of less grittiness in *Vaccinium* spp. would suggest one reason for the greater horticultural potentialities of these plants as contrasted with *Gaylussacia*.

The wide specific variation found in stone cell concentration suggests the usefulness of this character in species and perhaps even varietal distinctions. The authors' studies point to the possibility of using stone cell abundance as further evidence that the diploid *Vaccinium tenellum* has entered into the make-up of the hexaploid *V. ashei* (Rabbiteye) as held by Camp (2). Camp has considered the presence of glandular-tipped hairs on the lower surface of the leaves of both *V. tenellum* and *V. ashei* as an important criterion for establishing such a relationship. More extensive sampling of stone cell fre-

quency in the diploid, tetraploid, and hexaploid species from widely separated geographic areas would be highly valuable in the interpretation of interspecific relationships.

Since wide variation in the number of stone cells occurred in seedlings of *Vaccinium ashei* x *V. constablaei*, it would appear that this character should be given some emphasis in experimental breeding work. It seems possible to obtain horticultural varieties from crosses between forms of the above species which would combine the many other good qualities of these two species with freedom from stone cells. Experiments are now under way by the junior author which are planned to explore these possibilities.

Recent interest in the ontogeny of stone cells and other sclereids in vegetative organs by Foster (7, 8), Sterling (11), Bloch (1), and others suggests the need for developmental studies of the stone cells in *Vaccinium* and in related *Gaylussacia*. The sequence of maturation of stone cells in these genera with respect to development of the endocarp presents an interesting problem. Eames and McDaniels (5) state that the endocarp layer in *Gaylussacia* is already present at an early stage in the ovary and that maturation of this tissue as well as the flesh of the mesocarp does not involve cell divisions beyond the ovary stage.

Although, according to Engler and Prantl (6), placental enlargement is characteristic of the fruits of many Ericaceae, the hard, woody quality of this tissue in the material examined presents a problem in developmental anatomy. Studies now begun by the senior author are designed to describe the developmental history of stone cells and of endocarp and placental tissue in species of *Vaccinium* and *Gaylussacia*.

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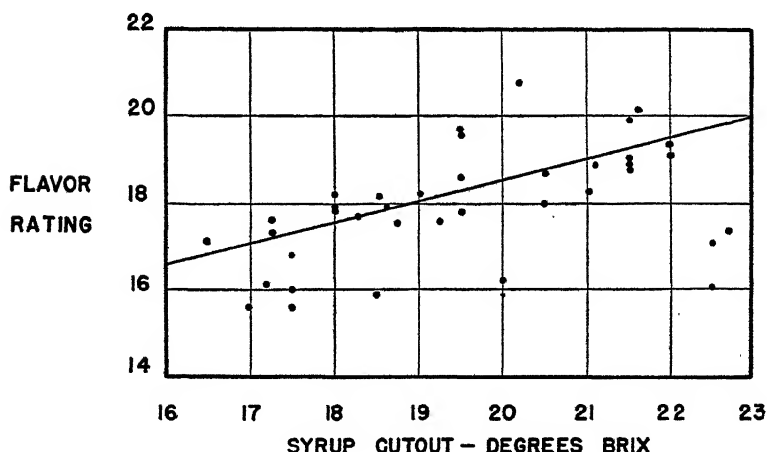
## Effect of Syrup Density on the Flavor Rating of Canned Peaches

By L. O. VAN BLARICOM, *South Carolina Experiment Station, Clemson, S. C.*

SINCE 1941 the Horticultural Products Research Laboratory of the South Carolina Experiment Station has been conducting experimental canned packs of a large number of peach varieties.

In judging the canned samples, a score of 25 per cent has been allowed for the factor of flavor. However, the judging of flavor has never been entirely satisfactory, and the factor of sweetness has influenced the scoring of flavor considerably.

Fig. 1 shows the syrup content in degrees Brix plotted against the flavor rating of 38 varieties of peaches. Each point represents the average judging score of 12 people. The position of the line was determined by the least-squares method of calculating a straight line trend. As the chart shows, when the syrup content becomes greater, flavor rating is higher.



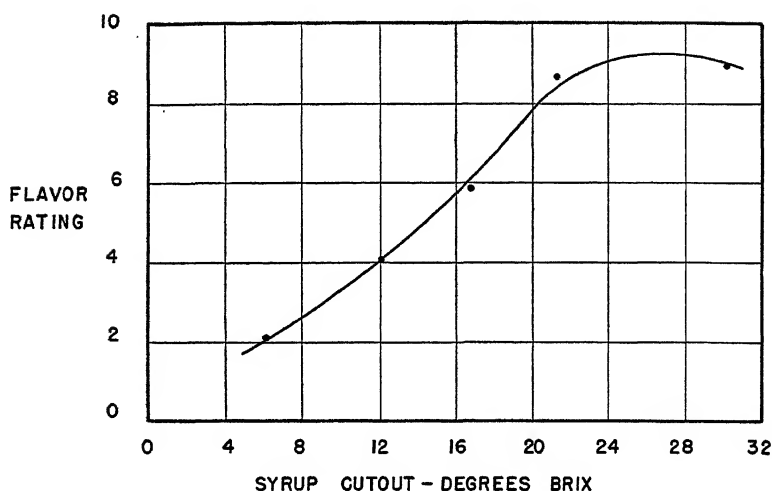


FIG. 2. Correlation of flavor and syrup in canned Elberta peaches.

again there was a decided increase in flavor rating with an increase in sugar content up to 20 or 25 per cent.

There are probably two reasons for this increased flavor rating with higher sugar content. First, the high concentrations of sugar preserve the flavor better than the lower concentrations, and second, but probably the more important, higher sugar content influences the taster to give a higher flavor rating because of the greater sweetness rather than because of improved flavor.

These graphs indicate that if canned peaches or other fruits are to be judged on flavor, then the sugar content must be regulated carefully so that all samples are uniform.

## Breeding For Earliness In Vine Crops

By A. F. YEAGER, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

THE inherent earliness of a crop is the result of the interaction of many genes. It is not a unit character. Increased earliness can therefore be best obtained by a careful study of the plant and by separating the factors, if possible, which make for earliness. We may then add one of those to an already desirable early variety lacking in that particular characteristic.

In muskmelons, our ordinary varieties, even the earliest, are either monocious or andromonocious which results in the plant first producing a large number of staminate flowers during the first weeks of its growth and not producing a pistillate or perfect flower until the plant lengthens and branches. It is on these side branches that perfect or pistillate flowers are formed. Since it is impossible for a plant to set fruit until such blossoms do appear, the plant for this reason must grow to a considerable size before it begins fruiting. If the very first flowers which are normally staminate were perfect blossoms and capable of setting fruit, the plant obviously might set its fruit much earlier in the season and therefore mature it earlier than those fruits which are produced from blossoms formed later in the season.

Among the United States Department of Agriculture foreign muskmelon plant introductions was one which the writer procured under the number 236-B, which has perfect flowers. This muskmelon, while early, has fruits which are nearly inedible. They are thin, white-fleshed, slender, extremely soft and acid. Crosses were made between this variety and a high quality standard early sort with the object of adding perfect flowers to it. Selections have been made in succeeding years which, while they do not have real market quality, set their fruit extremely early and ripen them early in the season. There seems to be little question but that eventually it will be possible to bring together the factors which make for extreme earliness in ordinary high quality muskmelon varieties and the perfect flower characteristics derived from 236-B. This should give mature muskmelons in less time from planting than has been possible up to this time.

In breeding for earliness in squashes (*Cucurbita maxima*) we have taken a somewhat similar approach. The Buttercup variety, which possesses high quality and considerable earliness but which is of the normal long vining type, was crossed with Zapolita, a plant introduction of the same species, which has poor cooking quality but which produces pistillate flowers and sets fruit at the crown instead of 5 to 10 feet out on long vines. Recombining the desirable characteristics of these two varieties has resulted in what we call the Bush Buttercup squash. This has high quality, a shape and size somewhat similar to the Buttercup, and the plants set one to three fruits within a foot of the ground. During the time that these fruits are developing, the plant has the appearance of a bush summer squash. Later in the season it may produce long vines which also set fruits. It is not, therefore,



strictly a bush variety; nevertheless, this early pistillate blooming characteristic does cause the plants to set their fruits earlier, to ripen them earlier and thus we have a variety which will give us high quality squash that will ripen and produce seed north of the White Mountains in New Hampshire where the average growing season is about a hundred days. Continued breeding is being done in the direction of small, high quality blue squashes by crossing Bush Buttercup with Blue Hubbard.

At present, selections in the F-4 generation are of two fruit types: one a small Blue Hubbard, the other a flat blue squash without the turban which characterizes Buttercup. Such varieties should have value at least in the home gardens, where space is a factor and extra earliness desirable.

A technique used in our squash breeding which saves labor is the use of terminal soft wood cuttings from field selected plants which, treated with hormones, will root in a few days in a cutting bench.

By using such cuttings we need not self-pollinate plants in the field. We merely propagate them asexually, set the rooted plants in the greenhouse, and self them there.

Cuttings made September first will produce ripe squash before January first, and since we may have several plants from each field selection, selfing is simplified and selfed seed secured in great abundance.

## Progress Report on Chemical Weed Control in Blueberry Fields

By W. W. SMITH, A. R. HODGDON, and RUSSELL EGGERT,  
*University of New Hampshire, Durham, N. H.*

**H**ARVESTING the fruit of the wild low-bush blueberry (*Vaccinium angustifolium* Ait. and *V. lamarckii* Camp) has become an important horticultural industry in New Hampshire. Profitable production in the low-bush blueberry field is maintained by control of weeds and by pruning the blueberry plants. Pruning is accomplished by burning the area over once in three years. Eradicating the weed plants is more difficult. Such weed plants as white pine and juniper bushes are eliminated by the burning. But, weed plants such as hardhack (*spiraea tomentosa*), and sweet fern (*Comptonia peregrina*) and lambkill or sheep laurel (*Kalmia angustifolia*) are not killed by the fire, but are even invigorated. These weeds may be controlled by continuous cutting in July, but this is an expensive process and takes several years. If a herbicide could be applied that would kill the weeds without injuring the blueberry plant, it would make possible the reclaiming of good blueberry fields that are now hopelessly covered with weeds. It would prevent the abandoning of blueberry fields such as is taking place every year because of the prevalence of weeds. It would also make possible the establishing of profitable blueberry fields in new areas where the weeds and blueberries are developing together.

In 1942, weed control plots were established in blueberry fields that had been abandoned because of the abundance of various weed plants. As a part of this weed control project, certain plots were treated with chemicals. In the areas infested with sheep laurel, lime was applied in the hope that raising the pH of the soil would make it unsuitable to the sheep laurel and still be acid enough for the blueberries. Applications of 1,000 and 2,000 pounds per acre were made, but to date, there seems to be no effect whatsoever upon the blueberries or the sheep laurel.

Boron has been suggested as an economical herbicide and recent investigations indicate that it has a place in weed control (1, 7).

Borax,  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10(\text{H}_2\text{O})$  was broadcast in September at varying rates from  $\frac{1}{2}$  to 2 pounds per 100 square feet, with no effect on the blueberry plants.

TABLE I—EFFECT OF BORAX (GRANULAR) ON BLUEBERRY WEEDS

Date	Pounds Per 100 Sq Ft	Name of Weed	Apparent Effect	Recovery
Jun 17, 1943.....	1	Sweet Fern	Injured	Complete
Jul 15, 1944.....	3	Sweet Fern	Injured	Complete
Jun 17, 1943.....	1	Hardhack	Killed	None
Jul 15, 1944.....	2	Hardhack	Killed	None
Jun 17, 1943.....	1	Sheep Laurel	Injured	Complete
Jun 17, 1943.....	1	Huckleberry	Defoliation	Complete
Jun 17, 1943.....	1	Bracken	Injured	Complete
Jul 15, 1944.....	2	Bracken	Injured	Complete
Jun 17, 1943.....	1	Hay-scented Fern	Injured	Complete

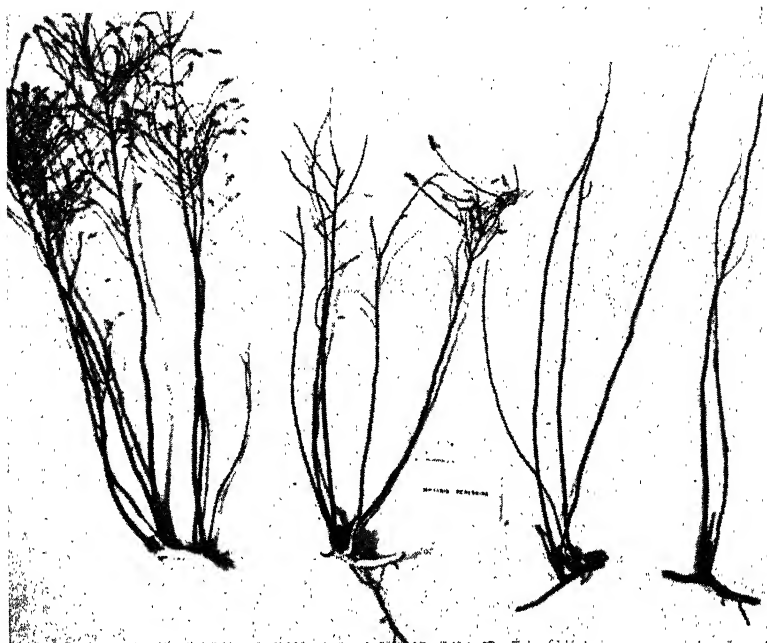


FIG. 1. Two sweet fern (*Comptonia peregrina*) plants at right killed with 2,4-D spray, two at left untreated.

Blueberry plants in these plots were uninjured. Hardhack (*Spiraea tomentosa*) was killed with 1- or 2-pound applications. Other plants present were injured as indicated in Table I, but completely recovered the following spring.

Ammonium sulfamate is technically a contact and translocation herbicide. In 1941 (6), it was found to be a more suitable herbicide than sodium chlorate for eradicating chokecherry. It is also excellent for poison ivy (12).

Aqueous solutions of ammonium sulfamate were sprayed on the blueberry plants as indicated in Table II.

Concentrations of 2 pounds of ammonium sulfamate per gallon killed sheep laurel. One pound or less per gallon injured this plant

TABLE II—EFFECTS OF AMMONIUM SULFAMATE SPRAYS ON BLUEBERRY WEED PLANTS (1942)

Date	Pounds Per Gal	Weed	Apparent Effect	Recovery
Aug 26.....	$\frac{3}{4}$	Sweet fern	Killed	None
Aug 26.....	$\frac{3}{4}$	Spiraea	Killed	None
Aug 26.....	$\frac{3}{4}$	Hay-scented fern	Injured	Complete
Aug 12.....	$\frac{3}{4}$	Huckleberry	Injured	Complete
Aug 12.....	2	Laurel	Killed	None
Aug 12.....	1	Laurel	Injured	Part
Aug 12.....	$\frac{3}{4}$	Laurel	Injured	Part



FIG. 2. Set of crowns of two sweet ferns (*Comptonia peregrina*) at right, killed with 2,4-D spray; plant at left is check.

but did not eradicate it. Sweet fern and hardhack were killed when sprayed with concentrations of  $\frac{3}{4}$  pound ammonium sulfamate per gallon. Raspberries, hay-scented fern and huckleberries were injured but not killed at this concentration.

It was noted within a week after treatment that all blueberry plants in these plots were severely injured. Plots were then treated with lower concentrations of ammonium sulfamate to determine susceptibility of the blueberry plant to this material (Table III).

TABLE III—LOW BUSH BLUEBERRY SPRAYED WITH AMMONIUM SULFAMATE (SEPTEMBER 5, 1942)

Concentration Pounds Per Gallon	Apparently Killed (Per Cent)	Recovery by 1946
$\frac{1}{32}$	50	Completely
$\frac{1}{16}$	75	Mostly
$\frac{1}{8}$	90	Partly
$\frac{1}{4}$	100	Slightly
$\frac{1}{2}$	100	None

Ammonium sulfamate at concentrations as low as  $\frac{1}{32}$  pound per gallon was injurious to blueberry plants, and  $\frac{1}{2}$  pound per gallon killed them.

2,4-Dichlorophenoxyacetic acid when applied as an aqueous spray has been found to have differential herbicidal properties (10, 4, 5).

Hamner and Tukey (5) found aqueous sprays of 2,4-D to be more effective on woody plants in warmer weather, and when leaves are fully expanded. Most plants sprayed in June were killed more quickly than when sprayed in April.

Mitchell and Brown (11) found 2,4-D more effective on the bean plant (*Phaseolus vulgaris*) when applied at the time of translocation of elaborated organic food materials, and indicate an association of movement of 2,4-D with translocation of organic food materials in this plant.

Hodgdon (8) found the common buttercup (*Ranunculus acris*) more easily killed with ammate sprays when the plant was mature than at earlier stages.

Marth and Davis (9) found sprays of 2,4-D were more effective when plants were at higher temperatures (75 to 90 degrees F).

Plots containing weed plants and blueberry plants were sprayed with aqueous solutions of the 2,4-D acid and ammonium salt of 2,4-D in June and July when plants were mature and the weather warm, as indicated in Table IV.

TABLE IV—EFFECTS OF 2,4-D SPRAYS ON BLUEBERRY AND ASSOCIATED WEEDS (APPLIED JUNE 27, 1945)

Treatment	Weed	Effect
Acid (1,000 ppm).....	Bracken	No injury
Acid (1,000 ppm).....	Lycopodium	No injury
Acid (1,000 ppm).....	Blueberry	Killed
Ammonium salt (1,000 ppm).....	Brakes	Injured
Ammonium salt (1,000 ppm).....	Maple	No injury
Ammonium salt (1,000 ppm).....	Wild strawberry	No injury
Ammonium salt (1,000 ppm).....	Wild raspberry	No injury
Ammonium salt (1,000 ppm).....	Blueberry	Killed
Ammonium salt (1,000 ppm).....	Spiraea	Killed

In these plots 2,4-D acid at 1,000 parts per million was ineffective on brakes and lycopodium but killed the blueberries. Ammonium salt of 2,4-D at 1,000 parts per million was ineffective on maple, wild strawberries and wild raspberries, but injured the brakes, and killed the blueberry and spiraea plants.

Grigsby (3) reported raspberry plants uninjured by sprays of 2,4-D at 1,000 parts per million. In the article, "2,4-D Control for Woody Vegetation" (2) maple and sheep laurel are listed as plants difficult to control with 2,4-D.

In another series of plots (Table V) in which sweet fern and blueberries were present, sprays of the acid and the ammonium salt of

TABLE V—EFFECT OF 2,4-D SPRAYS ON SWEET FERN (*Comptonia peregrina*) (APPLIED JUNE 27, 1945)

Treatment	Sweet Fern	Blueberry
Ammonium salt 1,000 ppm.....	Killed	Injured, dead
Acid 1,000 ppm.....	Killed	Injured, dead
Weedone, recommended.....	Killed	Injured, recovered

2,4-D at 1,000 parts per million killed the sweet fern and injured the blueberries to the extent that they were dead the following spring. Applications of "Weedone" applied as recommended killed the sweet fern and injured the blueberry plants, but the blueberry plants recov-

ered. Since the concentration of 2,4-dichlorophenoxyacetic acid in the Weedone used was lower than 1,000 parts per million, it suggested a less concentration of 2,4-D might not harm the blueberries and still kill some weeds. Consequently, in 1946 treatments as shown in Table VI were made.

In 1946, plots were sprayed (see Table VI) with the ammonium salt of 2,4-D at 1,000, 500, and 333 parts per million. Sweet fern was killed in all plots. Blueberry plants were injured by the 1,000 parts per million spray, but were not injured by 500 or 333 parts per million spray.

TABLE VI—EFFECT OF 2,4-D SPRAYS ON SWEET FERN (*Comptonia Peregrina*) AT LOWER CONCENTRATION (APPLIED JUNE 14, 1946)

Treatment	Sweet Fern	Blueberry
Ammonium salt 1,000 ppm.....	Killed	Injured
Ammonium salt 500 ppm.....	Killed	No injury
Ammonium salt 333 ppm.....	Killed	No injury

### SUMMARY

1. At the concentrations used lime had no effect on the weed plant sheep laurel or on the blueberry plants.

2. Ammonium sulfamate effectively killed some woody weed plants but was especially toxic to blueberry plants.

3. Borax (granular) in the concentrations used temporarily injured several weed plants and killed hardhack (*Spiraea*) without injuring the blueberry plant.

4. Sprays of the ammonium salt of 2,4-D and of 2,4-D acid at 1,000 parts per million killed blueberry plants.

5. Sprays of ammonium salt of 2,4-D at 500 and at 333 parts per million killed sweet fern without injuring blueberry plants.

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## Breeding for Cold Hardiness of Strawberry Flowers

By GEORGE M. DARROW and D. H. SCOTT, *U. S. Plant Industry Station, Beltsville, Md.*

FOR the past three years severe frosts at the time strawberry plants were in bloom have afforded an opportunity to observe differences in resistance to low temperatures. Three different frosts in 1947, with the third one exceptionally severe on May 10 when most varieties were in full bloom, showed outstanding differences in hardiness among varieties and seedlings.

Table I shows the temperatures that prevailed at the critical periods in 1947. The minimum thermometer in the weather shelter was 5 feet from the ground, and the ones at stations A, B, and C were 6 inches from the ground. The May 10 freeze was so severe that flowers and buds were killed on commercial varieties under a light straw mulch of about 2 tons per acre.

TABLE I—TEMPERATURES PREVAILING IN THE STRAWBERRY FIELD AT BELTSVILLE, MARYLAND IN 1947 AT CRITICAL PERIODS

Station	Dates of Freezes			
	April 28 (Degrees F)	April 29 (Degrees F)	May 9 (Degrees F)	May 10 (Degrees F)
A.....	23.0	22.0	22.5	19.0
B.....	23.0	22.0	22.5	18.5
C.....	23.5	22.5	23.0	19.0
Shelter.....	27.0	26.0	26.0	23.0
Time at minimum in shelter (hours).....	2	4	2	½

In 1937 A. F. Yeager sent several selections of *Fragaria virginiana* from North Dakota, from which, after testing, two were saved. These selections had been made by him on the basis of winter hardiness and other plant qualities. At Beltsville they have shown three notable qualities: extreme earliness, many flower clusters per plant, and frost resistance of flowers. For example, on April 11, 1946, with a temperature of 23 degrees F in the thermograph shelter about 300 feet distant, the selection from Fairmont, North Dakota, (elevation 985 feet) had no flowers injured out of many hundreds, and that from Sheldon, North Dakota, (elevation 1080 feet) had only 10 per cent of its flowers injured.

Crosses were made of these two selections with Midland, and 460 seedlings were put in the field in 1946. Each seedling was given a chance to mat in an 18-inch square of plants. All other records on varieties and selections were obtained from 12-foot or 24-foot matted-row plots. The flower counts were made on open flowers and were taken as soon as injury was visible to the unaided eye — usually about 10 o'clock in the morning after the freeze.

Table II shows the pronounced frost resistance of the two North Dakota *Fragaria virginiana* selections, especially of the Sheldon, in comparison with other *F. virginiana* selections and with varieties in



TABLE II—RESISTANCE OF FLOWERS OF STRAWBERRY VARIETIES TO FROSTS AT BELTSVILLE, MARYLAND, AT FOUR DATES IN 1947

Vareity	April 28 (Degrees 23 F)			April 29 (22 Degrees F)			May 9 (23 Degrees F)			May 10 (19 Degrees F)		
	Alive	Dead	Alive (Per Cent)	Alive	Dead	Alive (Per Cent)	Alive	Dead	Alive (Per Cent)	Alive	Dead	Alive (Per Cent)
Blakemore.....	3	31	9	5	35	13	2	98	2	0	100	0
Dorsett.....	2	11	15	0	22	0	—	—	—	—	—	—
Suwannee.....	3	35	8	7	47	13	1	99	1	1	199	0.5
Midland.....	17	12	59	13	42	24	0	100	0	0	200	0
Howard 17.....												
Plot 1.....	12	30	29	20	69	22	15	85	15	—	—	—
Plot 2.....	23	47	33	31	45	41	26	74	26	13	187	7.0
Early Cheyenne 1.....	15	10	60	12	30	29	43	57	43	23	177	12.0
Cheyenne 1206.....	—	—	—	141	59	71	52	48	52	69	131	35.0
Cheyenne 1225.....	51	92	36	55	152	27	16	84	16	11	189	6.0
<i>Fragaria ovalis</i>												
Cheyenne A 36979.....	53	23	70	68	47	59	—	—	—	—	—	—
<i>Fragaria virginiana</i>												
Fairmont, N. D.....	151	8	95	182	12	93	79	41	66	104	81	56.0
Sheldon, N. D.....	199	6	97	247	13	95	89	11	89	164	36	82.0
No. 27 (N. C.).....	—	—	—	—	—	—	30	70	30	20	130	13.0
var. <i>illinoensis</i>												
(La.).....	—	—	—	—	—	—	2	98	2	19	181	10.0

adjoining plots under the extreme conditions of May 10. A selection of *F. ovalis* from the Cheyenne, Wyoming, collection showed considerable hardiness for April 28 and 29, while selections from the Cheyenne breeding work (Early Cheyenne 1 and Cheyenne 1225 and 1206) had some resistance. Howard 17 (Premier) is commonly regarded as the most frost-resistant variety in the United States, and Havis (3) has recorded observations on its frost resistance in Ohio. Confirmation of this quality in comparison with other varieties was obtained, as is shown in Table II, Howard 17 had 78 flowers dead and 35 (31 per cent) alive following the 23 degrees F field temperature, and 114 dead and 51 (31 per cent) alive following the 22 degrees temperature; in contrast, Dorsett had 11 dead and 2 alive, and 22 dead and 0 alive following the respective temperatures.

The frost resistance of the seedlings from the crosses and of selected seedlings in the progenies is shown in Table III. As compared with the parent varieties, all of the seedlings blossomed early, so that most had a few flowers open on the April 28 date and some had many, as the counts indicate. Powers (4) has shown that in the *Fragaria ovalis* selections used as parents at Cheyenne, the early-blossoming habit was partially dominant, and apparently the same is true of the two *F. virginiana* selections used at Beltsville.

The data in Table III show that in the April 28 reading flowers of seedlings (counted at random) were injured less severely than those of the susceptible parent, although there was considerable killing of the blossoms. Some seedlings selected for flower hardiness were as hardy as the hardy parents at each freeze. In the May 9 and 10 freezes, though only a few of the seedlings were as tender as the tender parent, there was a wide range in hardiness of the seedlings. Consequently it appears that the cold-hardiness of the two *Fragaria virginiana* selections is transmitted as a quantitative character.

TABLE III—BLOSSOM AND FLOWER BUD HARDINESS OF STRAWBERRY SEEDLINGS TO FROSTS AT BELTSVILLE, MARYLAND, (1947)

	23 Degrees F (April 28)				22 Degrees F (April 29)				19 Degrees F (May 10)				Flower Bud Hardiness	
	Flowers				Flowers				Flowers				May 13	
	No. Clons	Alive	Dead	Per Cent Alive	No. Clons	Alive	Dead	Per Cent Alive	No. Clons	Alive	Dead	Per Cent Alive	No. Clons	Grade*
<i>Seedlings</i>														
<i>Fragaria virginiana</i>														
Sheldon X Midland ..	28	693	256	73	—	—	—	—	—	—	—	—	28	4.96
Sheldon X Midland ..	10	133	59	69	—	—	—	—	—	—	—	—	10	4.6
<i>Fragaria virginiana</i>														
Fairmont X Midland.	28	518	205	72	—	—	—	—	—	—	—	—	28	5.0
Fairmont X Midland.	28	322	122	73	—	—	—	—	—	—	—	—	28	4.71
Fairmont X Midland.	38	470	187	72	—	—	—	—	—	—	—	—	38	4.84
<i>Varieties</i>														
<i>Fragaria virginiana</i>														
Sheldon.....	10	199	6	97	10	247	13	95	10	164	36	82	10	7.0
Fairmont.....	10	151	8	95	10	182	12	94	10	104	81	56	10	6.0
Midland.....	10	17	12	59	10	3	23	12	10	0	200	0	19	1.3
<i>Seedling Selections</i>														
<i>Fragaria virginiana</i>														
Sheldon X Midland														
102-12.....	1	10	0	100	1	18	4	82	—	—	—	—	1	4.0
102-13.....	1	60	10	85	1	60	26	70	—	—	—	—	1	4.0
102-15.....	—	105	7	93	1	279	50	85	1	143	57	72	1	7.0
102-17.....	1	145	23	86	1	319	49	87	1	92	108	46	1	6.0
103-8.....	1	23	2	92	1	39	6	87	1	115	41	74	1	7.0
<i>Fragaria virginiana</i>														
Fairmont X Midland														
106-3.....	—	21	4	84	—	93	16	85	—	—	—	—	1	5.0
106-15.....	—	20	5	80	—	76	14	84	—	—	—	—	1	5.0
106-23.....	—	25	0	100	—	126	17	88	—	—	—	—	1	6.0
106-26.....	—	23	2	92	—	89	21	81	—	—	—	—	1	6.0
107-16.....	—	20	4	83	—	72	8	90	—	—	—	—	1	6.0
107-18.....	—	24	1	96	—	38	6	86	—	—	—	—	1	6.0

\*Grades were as follows: 1 = 0 flowers alive, 2 had 1 to 20 per cent alive, 3 had 21 to 40 per cent alive, 4 had 41 to 60 per cent alive, 5 had 61 to 80 per cent alive, 6 had 81 to 90 per cent alive, 7 had 91 to 100 per cent alive.

All seedlings were rated for flower and bud hardiness on May 13, after many buds had opened following the frosts of May 9, 10, and 11, and the results are recorded in Table IV. An adjacent cross, E. Roosevelt x. Massey, was also rated. A few of its seedlings had a fair number of uninjured open flowers. Among the hardy crosses a large number had most of their flowers uninjured, and there were many hardy seedlings from which to select.

The berry size of the seedlings ranged up to half the size of Midland, though most were much smaller. Very few had fruit as small as the wild parent. Nearly all the berries were soft, though not so soft as those of crosses of *Fragaria ovalis* x Gold Dollar in Oregon. A few were fairly firm. The flavor of the fruit was good to excellent, many having a delightful aroma. The pistillate seedlings were generally productive, but those having stamens in their flowers ranged from almost completely sterile plants to productive ones.

Practically all plants were very vigorous. Though some seemed

TABLE IV—FLOWER AND BUD HARDINESS OF STRAWBERRY SEEDLINGS AND VARIETIES ON MAY 13, 1947 (FOLLOWING 19 DEGREES F TEMPERATURE ON MAY 10)

	Per Cent Live Flowers and Number Seedlings in Each Class								Average Per Cent Flowers Alive
	0 No.	1-20 No.	21-40 No.	41-60 No.	61-80 No.	81-90 No.	91-100 No.	Total No.	
Seedlings									
E. Roosevelt X Massey.....	55	23	15	2	—	—	—	95	8.0
<i>Fragaria virginiana</i>	0	2	26	68	87	45	4	232	62.0
Sheldon X Midland.....	0	1	31	65	74	65	7	243	64.0
Fairmont X Midland.....									
Varieties									
Midland.....	14	5	—	—	—	—	—	19	2.6
Suwannee.....	11	17	—	—	—	—	—	28	6.1
<i>Fragaria virginiana</i>									
Sheldon.....	—	—	—	—	—	—	10	—	95.0
Fairmont.....	—	—	—	—	—	10	—	—	85.0

susceptible to leaf spot, leaf scorch, and a few to mildew, it is probable that more time than is usual for varieties is required for general infection by these diseases. Runners were produced freely. Some flowered a little in the fall, as is characteristic of many seedlings from crosses of *Fragaria ovalis* (those selected at high elevations, at least).

Hansen (2) reported on breeding for hardiness in South Dakota. He raised some 8,000 seedlings of hardy wild crossed with cultivated varieties, which were exposed to winter temperatures of -40 degrees F without covering, and the selected seedlings were propagated. Selections fully hardy at Brookings, South Dakota, were backcrossed to varieties and hardy seedlings were selected from the resulting populations. These 1/4 wild were still small, but had fruit up to 1 inch in diameter.

Georgeson (1) used selections of *Fragaria ovalis* (*F. platypetala*), which thrives where temperatures go to -70 degrees F, from Fairbanks, Alaska, in breeding and succeeded in obtaining selections hardy at Fairbanks.

#### SUMMARY

Selections of the meadow strawberry, *Fragaria virginiana*, show great differences in flower and bud hardiness to frost, some being far more hardy than any cultivated varieties. Selections having frost-resistant flowers, when crossed with the cultivated variety Midland, transmitted frost resistance in a high degree to their seedlings.

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# The Influence of Temperature on the Photoperiodic Response of Several Strawberry Varieties Grown Under Controlled Environment Conditions

By H. T. HARTMANN, *University of California, Davis, Calif.*

IN the strawberry districts of the coastal fruit sections just south of San Francisco some of the highest known strawberry yields have been reported (6). This is due to the fact that in this region the strawberry has not only the usual spring crop but additional harvest periods throughout the summer and fall. Excluding the true everbearing types, the strawberry is considered to be a short-day plant, its fruit-buds being differentiated during the short days of fall and winter (3). With the advent of the long days of summer the reproductive state is replaced by the vegetative condition as evidenced by runner production in most varieties. In the previously mentioned section of California, the days become long enough (15 hours in June) to cause initiation of runners. However, the environmental conditions are such that the differentiation of flower buds also continues which is followed by production of ripe fruits. The same varieties grown but one hundred miles to the east in the Sacramento and San Joaquin valleys of California bear only the usual spring crop. The day-length conditions in the coastal sections and interior valley sections are the same but the temperatures during the summer are very different. An average temperature of 62.7 degrees F (1) is found in the Watsonville area on the coast during July. In Sacramento in the interior valley the average temperature is 73.9 degrees F in July (1).

Darrow (2) and Darrow and Waldo (3) in studying the effects of photoperiod and temperature on the strawberry concluded that although the strawberry is a short-day plant, flower buds can be initiated during long days provided the temperature is low enough (60 degrees F or less). Their work was conducted under field and greenhouse conditions with a number of strawberry varieties and species.

## METHODS AND RESULTS

Strawberry plants were grown under controlled environmental conditions in equipment described in detail by Hartmann and McKinnon (4). This equipment consisted of a set of four environment-control cabinets which permitted the temperature to be maintained at desired levels by electric heaters and by refrigeration units, both thermostatically controlled. The plants were grown under banks of fluorescent lamps which maintained a light intensity of approximately 500 foot-candles at the level of the plants. The day-length conditions could be adjusted at will and were automatically maintained by a time switch operated by a synchronous electric motor.

Four varieties were used in this investigation: Marshall, Missionary, Fairfax, and Blakemore. They were grown under long days (normal day length plus supplementary incandescent illumination) for 2½ months in the greenhouse until the beginning of the test. The plants were grown in soil in gallon containers. On November-1, 1946,

six plants of each of the four varieties were placed under the following conditions in the environment-control cabinets: (a) long days (15 hours) at a constant temperature of 70 degrees F; (b) long days (15 hours) at a constant temperature of 60 degrees F; (c) short days (10 hours) at a constant temperature of 70 degrees F; and (e) short days at a constant temperature of 60 degrees F. Previous work (5) showed that floral initiation was similar in the strawberry whether the plants were grown under constant temperature or under the normal daily fluctuating temperature.

The plants maintained runner production for a short time after the beginning of the test treatment due to runner initials formed while the plants were under the long-day greenhouse conditions preceding the test. None of the plants produced any runners during the latter part of the test.

On December 4 the first flowers were formed and counts of the number of plants bearing flower clusters were made at intervals until February 20. The results of the flower counts are given in Table I.

TABLE I—EFFECT OF TEMPERATURE ON FLOWER FORMATION IN THE STRAWBERRY. NUMBER OF PLANTS BEARING FLOWER CLUSTERS OUT OF A TOTAL OF SIX PLANTS PER TREATMENT

Date	Marshall		Missionary		Fairfax		Blakemore	
	60 Degrees F	70 Degrees F	60 Degrees F	70 Degrees F	60 Degrees F	70 Degrees F	60 Degrees F	70 Degrees F
<i>Plants Grown in Long Days (15 Hours)</i>								
Dec 4.....	0	0	0	0	0	0	0	0
Dec 23.....	0	0	1	0	0	0	0	0
Jan 14.....	6	0	2	0	0	0	0	0
Jan 31.....	6	0	6	0	0	0	6	0
Feb 20.....	6	0	6	0	3	0	6	0
<i>Plants Grown in Short Days (10 Hours)</i>								
Dec 4.....	0	0	0	0	1	0	0	0
Dec 23.....	0	0	2	0	1	0	0	0
Jan 14.....	1	3	2	1	1	0	0	6
Jan 31.....	5	4	3	3	1	0	6	6
Feb 20.....	6	5	5	4	3	0	6	6

## DISCUSSION

All the varieties formed flowers when the temperature was maintained at 60 degrees F even though they were under long-day conditions. No flowers were formed by any of the four varieties under long-day conditions at a temperature of 70 degrees F. The plants held under short days initiated flowers at about the same rate at both 60 and 70 degrees F. The Fairfax variety, however, under short days failed to form flowers except at the lower temperature. These results would indicate that a reduction in temperature may be just as important in inducing flower formation in the strawberry as a short daily light period.

These results agree in general with the findings of Darrow (2) and Darrow and Waldo (3) that at low temperatures flower buds may form in the strawberry under long daily light periods.

While it was expected that runner production would occur in the plants under the 70 degrees-15 hour day-length treatment, this failed to take place. These plants were under the test conditions for almost 4 months which is enough time for runners to be initiated and to become macroscopically visible.

It would seem reasonable to conclude that the summer production of strawberry fruits in the coastal fruit sections south of San Francisco is probably due to the low mean temperature during the summer months which causes floral initiation in spite of the long days.

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## Quality Comparisons of Strawberry Varieties as Affected by Processing with the Freezing Method<sup>1</sup>

By A. LEE SCHRADER, *University of Maryland, College Park, Md.*, and D. H. SCOTT, *U. S. Department of Agriculture, Beltsville, Md.*

THE evaluation of newer strawberry varieties and promising new seedlings in regard to their relative merits when preserved in the frozen state deserves attention annually. As several investigators have pointed out, it is not safe to assume that a variety with a high quality in the fresh state will naturally make a high quality frozen product, nor should one disregard the effects of seasonal growing conditions, stage of maturity, or differences among the portions of the harvest in any one season.

In this study attention was centered on varieties and selections that appeared useful for freezing, based on fresh eating quality, firmness of flesh, and red color of the flesh. Samples for this work were obtained through the cooperation of the United States Department of Agriculture from the extensive test plantings at Beltsville, Maryland. The berries were grown in the same field under uniform conditions of culture that produced well-grown plants of each variety.

### METHODS

Samples were carefully sorted on the same day of harvest to limit the material for preservation only to berries of uniform ripeness. After sorting, the removal of caps (stemming) was followed immediately by washing thoroughly in cold water and draining a few minutes. With many varieties, hand stemming with the aid of a paring knife was essential to remove hard stem portions attached to the core. In 1944, all slicing was done by hand, but in 1946 a motor-operated Townsend slicer cut the samples in a few seconds into  $\frac{1}{8}$  inch slices which were immediately mixed with dry sugar to the desired ratio. In 1944, sugar was used at a ratio of three parts of berries to one of sugar, whereas in 1946 the ratio was changed to four to one to avoid excessive sweetness. Packing was done in small enamel-lined cans, known as "mushroom" cans, which were completely filled before closing, leaving no air space at the top. Freezing was accomplished in a freezing chamber with circulating air at  $-20$  degrees to  $-25$  degrees F and the frozen material was stored at 0 degrees F.

The samples after the storage period were judged in a thawed condition and scored for color, texture, and flavor, allowing 10 points maximum for each factor, or a total of 30 points for a perfect sample.

<sup>1</sup>Scientific Publication No. A162. Contribution No. 2057 of the Maryland Agricultural Experiment Station (Department of Horticulture).

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After scoring, each judge was requested to vote on each sample as to whether or not it was acceptable to the consumer.

**1944 Pack:**—In Table I, the varieties have been arranged in order of their respective total scores. The three outstanding varieties were Tennessee Shipper, Midland, and Tennessee Beauty although the latter variety scored low when frozen as a whole berry. Fairpeake, Redstar, Bristol, and Chesapeake all were rated low as sliced berries

TABLE I—RELATIVE QUALITY RANKINGS OF STRAWBERRY VARIETIES PROCESSED BY THE FREEZING METHOD AND HELD TEN MONTHS AT 0 DEGREES F (1944 PACK)

Variety	Parentage	Stage of Ripeness	Average Score on:			Total Scores	Judges' Vote on Consumer Acceptance		
			Color	Texture	Flavor		Yes	?	No
<i>Sliced in Dry Sugar (3-1 Ratio)</i>									
Tenn. Shipper	M×B	Full ripe	9.3	10.0	9.3	28.6	3	—	—
Midland.....	R H×H 17	Very ripe	9.0	7.3	9.3	25.6	3	—	—
Tenn. Beauty	M×H 17	Full ripe	8.3	6.3	9.3	23.9	3	—	—
Fairpeake....	F×C	Full ripe	4.0	7.3	7.3	18.6	1	—	2
Redstar.....	C×F	Full ripe	3.7	6.3	7.0	17.0	—	1	2
Bristol.....	(C×M)×(P×H 17)	Soft ripe	6.0	5.0	5.3	16.3	—	2	1
U. S. 1453....	K×F	Very ripe	7.7	1.1	5.3	14.1	—	1	2
Chesapeake..	Unknown	Soft ripe	3.3	3.7	5.3	12.3	—	—	3
<i>Whole Berries in Dry Sugar (3-1 Ratio)</i>									
Midland.....	R H×H 17	Very ripe	10.0	7.7	9.7	27.4	3	—	—
Tenn Shipper	M×B	Full ripe	9.0	10.0	8.0	27.0	3	—	—
U. S. 1453....	K×F	Very ripe	6.7	5.7	6.7	19.1	2	1	—
Chesapeake..	Unknown	Soft ripe	5.7	6.7	6.7	19.1	1	1	1
Bristol.....	(C×M)×(P×H 17)	Soft ripe	6.3	6.0	6.7	19.0	2	—	1
Fairpeake....	F×C	Full ripe	5.7	7.7	5.3	18.7	2	—	1
Tenn. Beauty	M×H 17	Full ripe	5.3	6.0	6.0	17.3	2	—	1

and considered unacceptable to the consumer, but these varieties when frozen as whole berries improved in scores materially (except Fairpeake). In the sliced form, Fairpeake and Redstar exhibited a poor color of pale whitish pink; Chesapeake had the same poor color as well as too soft texture, and Bristol was poor in texture and flavor. Chesapeake would have appeared to better advantage if the berries had been harvested in a firm to full ripe condition instead of soft ripe as noted. Likewise, U. S. 1453, originally saved for its freezing possibilities, would have scored much higher if the berries had not been on the over-ripe side, and evidence for this statement is found in the results of 1946. Although total score was not used as a criterion for consumer acceptance, all samples that scored less than 20 in total points out of a possible 30 were voted either as not acceptable for the consumer or open to question. It can also be noted that a score of less than 5 for color, texture, or flavor was quite certain to place a variety as unacceptable. The results of this 1944 pack emphasized the importance of two factors, first the differences among varieties as to texture and color, and second, the necessity of having the berries of any given variety at the proper stage of maturity for freezing of that variety.



1946 Pack:—In Table II, a subdivision has been made to place the samples in four groups depending on the votes of the judges on consumer acceptance, and within each group the varieties are arranged in order of their total scores. A high total score of 20 or more was

TABLE II—RELATIVE QUALITY RANKINGS OF STRAWBERRY VARIETIES PROCESSED BY THE FREEZING METHOD AND HELD FOR FIVE MONTHS AT 0 DEGREES F

Variety	Parentage	Date of Harvest	Stage of Ripeness	Average Score on			Total Score	Judges' Vote on Consumers Acceptance		
				Color	Texture	Flavor		Yes	?	No
Group I: Unanimously Acceptable										
U. S. 2644*...	R H×B	May 31	Full ripe	9.7	9.0	8.8	27.5	6	—	—
U. S. 2644....	R H×B	May 31	Full ripe	9.0	8.8	9.2	27.0	6	—	—
U. S. 1453....	K×F	Jun 7	Full ripe	9.2	6.8	8.4	24.4	6	—	—
Tenn. Beauty	M×H 17	Jun 10	Full ripe	8.3	6.8	8.4	23.5	6	—	—
Suwannee....	M×H 17	Jun 3	Full ripe	6.3	7.5	9.2	23.0	6	—	—
Blakemore*...	M×H 17	May 29	Firm ripe	7.5	7.3	8.2	23.0	6	—	—
Sierra.....	Nick Ohmer× Cal 177.21	Jun 7	Full ripe	7.3	6.3	8.8	22.4	6	—	—
Blakemore....	M×H 17	May 29	Firm ripe	6.2	7.0	7.0	20.2	6	—	—
Average....				7.9	7.4	8.5	23.9			
Group II: Almost Unanimously Acceptable										
Brightmore...	B×Ore. 154	May 31	Full ripe	9.0	6.8	6.8	22.6	5	—	1
Dorsett.....	R S×H 17	May 29	Full ripe	9.2	6.2	6.7	22.1	5	—	1
U. S. 3241....	C×D	Jun 7	Full ripe	8.0	6.3	7.8	22.1	5	1	—
Shasta.....	Cal. 67.5×Cal. 177.21	Jun 10	Full ripe	7.3	6.3	8.2	21.8	5	1	—
Suwannee*...	M×H 17	Jun 7	Full ripe	7.3	7.2	7.2	21.7	5	—	1
Blakemore....	M×H 17	May 31	Firm ripe	6.0	8.0	6.3	20.3	4	2	—
Average....				7.8	6.8	7.2	21.8			
Group III: Divided Opinion—Borderline Cases										
Redwing.....	N J 46×F	Jun 10	Full ripe	7.3	5.3	7.8	20.4	4	1	1
Midland.....	R H×H 17	May 29	Firm ripe	6.6	6.4	7.2	20.2	3	2	1
U. S. 3205*...	F×A	May 29	Full ripe	7.7	6.0	6.0	19.7	3	—	3
Tenn. Beauty	M×H 17	Jun 3	Firm ripe	7.0	6.5	6.0	19.5	2	2	2
U. S. 3205....	F×A	May 29	Full ripe	5.8	5.8	7.0	18.6	4	1	1
Tenn. Shipper	M×B	May 31	Firm ripe	5.7	6.8	5.8	18.3	4	—	2
U. S. 3500....	Unknown	Jun 3	Full ripe	7.0	4.8	5.4	17.2	4	—	2
Average....				6.7	5.9	6.5	19.1			
Group IV: Unanimously Rejected										
U. S. 1453....	K×F	May 29	Full ripe	6.5	6.7	4.3	17.5	—	—	6
Fairfax.....	R S×H 17 or H 17×ET 450	Jun 3	Full ripe	2.8	5.0	3.8	11.6	—	—	6
Average....				4.7	5.9	4.1	14.6			

\*Whole Berries Key to Parentage:

R H—Redheart  
B—Blakemore  
K—Klondike  
M—Missionary  
H 17—Howard 17

R S—Royal Sovereign  
F—Fairfax  
A—Aberdeen  
C—Catskill  
Et—Ettersburg

closely correlated with a favorable vote on consumer acceptance, although in two instances, notably with Redwing and Midland in group 3, one must consider the scores for the specific factors. The unfavorable vote on these two varieties reflected the soft texture of Redwing (5.3) and the relatively poor color of Midland without compensating higher values in texture and quality.

In 1944, Midland was one of the best varieties, but its firm-ripe condition in 1946 was responsible for a much lower rating in the latter year, indicating that a full ripe or even very ripe condition is essential for good freezing quality of this variety. Other instances where degree of ripeness had a marked effect are found with Tennessee Beauty, Tennessee Shipper, and U. S. 1453. Whereas the Tennessee Beauty, picked June 10 in full ripe condition, scored high (23.5) and placed in group 1, an earlier picking on June 3 in firm-ripe condition scored below 20 and fell in group 3. Tennessee Shipper in a full-ripe condition was one of the best in 1944, but was harvested in firm-ripe condition in 1946 and scored only 18.3, to fall in group 3. The seedling U. S. 1453 presented the most extreme case, showing a very high rating (24.4) from full-ripe berries (harvested June 7) and a very low rating (17.5) from full-ripe berries harvested May 29, and likewise a very low rating (14.1) in 1944 with very ripe berries. The low quality of the May 29 picking of U. S. 1453 might be attributed to a rainy period preceding the harvest. It can be pointed out that with firm-ripe berries the scores for color and flavor are affected, and with very-ripe berries, the scores for texture and flavor are reduced. Blakemore, a standard freezing berry for preserve use, appears to develop enough color and quality in the firm-ripe stage to place it among the acceptable groups, but at this stage of ripeness it scored higher as a whole berry than as a sliced berry. Considering the four groups in Table I, it is evident from the average values that color, texture, and flavor all move downward with decrease in acceptability.

With attention to the factor of ripeness, the acceptable varieties from Tables I and II would include U. S. 2644, U. S. 1453, Tennessee Beauty, Tennessee Shipper, Midland, Suwannee, Blakemore, Sierra, Brightmore, Dorsett, U. S. 3241, and Shasta. Among varieties not acceptable would be Redwing, Red Star, Chesapeake, Bristol, Fairpeake, U. S. 3205, U. S. 3500, and Fairfax. Fairfax scored very low particularly because of lifeless color and insipid flavor, which is in agreement with the results of Lutz *et al* (1), but other workers have reported this variety as desirable for freezing.

It is interesting to note the parentage of the acceptable varieties in that Missionary and Howard 17 contribute most frequently to the crosses that result in good freezing quality. In the work of Lutz *et al* (1), it was reported that Missionary rated good as a freezing berry and Howard 17 rated fair to good. The detailed judging showed that each of these varieties had only fair flavor, but Howard 17 had good color and Missionary had firmness. Probably in the crosses Howard 17 contributed good color and Missionary added firmness.

In the freezing work of 1946, particular attention was paid to processing only those varieties that had firm flesh and red color throughout the berry, avoiding varieties or selections that had pinkish flesh or white centers, regardless of the flavor.

#### SUMMARY

Newer strawberry varieties and promising selections, grown by the United States Department of Agriculture at Beltsville, Maryland,

were processed by the freezing method in 1944 and 1946, using especially varieties with a firm flesh and red color throughout the berry. The frozen product, frozen at  $-20$  degrees to  $-25$  degrees F, was held in storage for 10 months in 1944 and for 5 months in 1946. Judged on the basis of color, texture, and flavor, the varieties and selections considered acceptable to the consumer were U. S. 2644, U. S. 1453, Tennessee Shipper, Tennessee Beauty, Midland, Suwannee, Sierra, Blakemore, Brightmore, Dorsett, U. S. 3241, and Shasta, probably in the order named. Those not acceptable were Redwing, U. S. 3205, U. S. 3500, Redstar, Fairpeake, Bristol, Chesapeake, and Fairfax, also included firm-ripe berries of Tennessee Beauty, Tennessee Shipper, and Midland, as well as very-ripe berries of U. S. 1453. Berries that were firm-ripe or under-ripe were low in color and flavor, whereas berries of very-ripe conditions were low in texture and flavor. On the average, color, texture and flavor all decreased as one moved from varieties of high rating to those of low rating. Missionary and Howard 17 were involved predominantly in the parentage of the varieties making a good frozen product.

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## Ascorbic Acid Content of Strawberry Varieties Before and After Processing by Freezing<sup>1</sup>

By L. E. SCOTT and A. LEE SCHRADER, *University of  
Maryland, College Park, Md.*

THE nutritive quality of the frozen product in terms of vitamin content is an important point to consider in the selection or recommendation of a strawberry variety or new seedling for freezing purposes. Thus, in connection with variety comparisons of strawberries for eating quality after processing by the freezing method (3), studies were made of the ascorbic acid content to ascertain, (a) the amount in the fresh berries, (b) the amount retained in the frozen product after 5 months of storage at 0 degrees F, and (c) the effect of storing the fresh berries at different temperatures before processing on the ascorbic acid content of the frozen product.

### METHODS

The preparation and processing of the fresh berries have been described in the report considering eating quality (3). Samples of the fresh product for ascorbic acid analysis were taken immediately following the slicing of the berries of a given lot before sugar was added, and approximately 100 grams of the well-mixed slices comprised a sample. A sample of the frozen product included the contents of one "mushroom" can. Duplicate determinations were made on 20 grams of each sample extracted for 2 minutes with 200 milliliters of 0.5 per cent oxalic acid in a Waring blender. The titration end-point on an aliquot of this blend was determined with a Fisher Titrimeter since the color of the berries made visual titration extremely difficult. Results of analyses were reported as milligrams per 100 grams of strawberry material, and in the case of the frozen product this required a calculation to adjust for the sugar added.

### RESULTS

In Table I, the ascorbic acid contents of the fresh strawberries are arranged in numerically descending order for the varieties and seedlings except the last six varieties for which values were not secured on the fresh material. The fresh berries showed a range in content of ascorbic acid from 50.0 milligrams for Blakemore to 85.3 mg/100 gm for U. S. 1453. The values in the main agree with those reported by Slate and Robinson (5) for the same varieties, although Slate and Robinson place Dorsett and Blakemore in a much lower category based on a figure of 49.0 for Dorsett and 42.0 milligrams for Blakemore as reported by Satterfield and Yarbrough (2). It is apparent that none of the varieties listed in Table I would fall below 50 mg/100 gm assuming that the value of 46.8 for frozen berries of Shasta represented a loss during storage of at least 3.2 milligrams.

<sup>1</sup>Scientific Publication No. A163. Contribution No. 2058 of the Maryland Agricultural Experiment Station (Department of Horticulture).

The ascorbic acid values of the frozen samples ranged from 46.8 to 64.1 mg/100 gm after 5 months of storage at 0 degrees F. There was a surprisingly high retention of ascorbic acid in comparison with the values reported by Mayfield and Richardson (1) and by Shimer *et al* (4) for similar length of storage after freezing. On a percentage basis (Table I) most of the varieties retained above 80 per cent of the value

TABLE I—ASCORBIC ACID CONTENT OF STRAWBERRY VARIETIES BEFORE AND AFTER PRESERVATION BY FREEZING

Variety	Parentage	Harvest Date	Ascorbic Acid in Mg 100 Gm		Ascorbic Acid Retained (Per Cent)	Fruit Condition Before Freezing
			Before Freezing	After Freezing		
U. S. 1453...	K X U S 613	May 29	85.3	47.8	56	Full ripe
U. S. 1453...	K X U S 613	Jun 7	76.7	60.4	79	Full ripe
Sierra.....	Nich. Ohmer X Calif. 177.21	Jun 7	78.2	56.4	72	Full ripe
U. S. 3241....	C X D	Jun 7	73.7	63.8	87	Full ripe
Fairfax.....	R S X H 17 or H 17 X ET 450	Jun 3	71.5	48.4	68	Full ripe
Suwannee....	M X H 17	Jun 3	70.7	60.0	85	Full ripe
Tenn. Beauty	M X H 17	Jun 3	61.5	52.8	86	Firm ripe
Tenn. Beauty	M X H 17	Jun 10	—	64.1	—	Full ripe
Redwing.....	N J 46 X F	Jun 10	59.3	60.0	100	Full ripe
Temple.....	A X F	May 28	58.0	49.1	85	Full ripe
U. S. 3500....	?	Jun 3	57.1	47.8	84	Full ripe
Midland.....	R H X H 17	May 29	56.5	51.1	90	Firm ripe
U. S. 3205....	F X A	May 29	55.5	47.4	85	Full ripe
Blakemore....	M X H 17	May 29	53.0	50.0	94	Firm ripe
Blakemore....		May 29	64.0	48.4*	76	Firm ripe
Dorsett.....	RS X H 17	May 29	—	64.1	—	Full ripe
Tenn. Shipper	M X B	May 31	—	64.1	—	Firm ripe
Brightmore...	B X Ore. 154	May 31	—	53.4	—	Full ripe
U. S. 2844....	R H X B	May 31	—	51.8	—	Full ripe
U. S. 2844....	R H X B	May 31	—	59.9*	—	Full ripe
Shasta.....	Calif. 67.5 X Calif. 177.21	Jun 10	—	46.8	—	Full ripe

\*Whole berries.

originally found in the fresh berries. The high retention of ascorbic acid in these lots may have resulted from packing the berries in cans completely filled, leaving no air-space above the berries. Agreeing with the report by Shimer *et al* (4), the varieties with high original ascorbic acid content tended to lose their content more readily after freezing, thus equalizing differences among varieties. The lowering of values for the fresh berries as the season advanced, also previously reported (4), is seen in the case of U. S. 1453.

In Table II, the effect of storing the berries before processing is shown to be very slight in relation to the ascorbic acid loss during such storage, and there was no measurable effect on the ascorbic acid content of the frozen product. The slight loss with the fresh berries agrees with results reported by Mayfield and Richardson (1).

#### SUMMARY

Strawberry varieties and seedlings of especial interest for their quality as a frozen product exhibited ascorbic acid contents ranging from 85.3 to 53.0 milligrams per 100 grams fresh material. After freezing and storage for 5 months, these varieties showed a high retention of ascorbic acid, averaging about 80 per cent and with few

TABLE II—ASCORBIC ACID CONTENT OF FROZEN STRAWBERRIES AS AFFECTED BY STORAGE TEMPERATURES OF THE FRESH FRUIT BEFORE FREEZING

Harvest Date	Storage of Fresh Fruit	Ascorbic Acid in Mg/100 Gm		Ascorbic Acid Retained (Per Cent)	Fruit Condition Before Freezing
		Before Freezing	After Freezing		
U. S. 3205					
May 29.....	None	55.5	47.4	85	Full ripe
May 29.....	2 days at 40 degrees F	—	51.8	—	Full ripe
May 31.....	4 days at 32 degrees F	52.3	45.4	87	Full ripe
May 31.....	4 days at 46 degrees F	49.7	48.1	97	Full ripe
Blakemore					
May 29.....	None	64.0	48.4	76	Firm ripe
May 29.....	2 days at 40 degrees F	—	50.8*	—	Full ripe
May 31.....	None	—	49.0	—	Firm ripe
May 31.....	2 days at 32 degrees F	51.5	41.8	81	Full ripe
May 31.....	2 days at 46 degrees F	60.5	48.4	80	Full ripe
May 31.....	2 days at 52 degrees F	55.4	48.1	87	Full ripe

\*Whole berries.

varieties below that figure. Storing fresh berries at different temperatures from 32 degrees F to 52 degrees F for 2 to 4 days had slight effect on the ascorbic acid content, and there was no measurable effect on the subsequent content of the frozen product after 5 months storage.

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## Results of Further Investigations on the Use of "Hormone" Sprays in Tomato Culture<sup>1</sup>

By A. E. MURNEEK, *University of Missouri, Columbia, Mo.*

IN a previous publication information has been presented on the results of extensive investigations on the effects of various synthetic growth substances ("hormones") on fruit set and size of greenhouse-grown tomatoes (1). Emphasis was placed on the comparative potency and value for this purpose of  $\beta$ -naphthoxyacetic (NOA) and p-chlorophenoxyacetic (CIPA) acids. Both of these chemicals had been used either as flower cluster or whole plant sprays. The most desirable concentrations found by us were: (a) *For flower cluster spraying*: NOA at 50 to 75 ppm or CIPA at 10 to 15 ppm. (b) *For whole plant spraying*: NOA at 15 to 20 ppm or CIPA at 1 to 2 ppm. The lower concentrations are suggested for cloudy weather, the higher when there is abundant light. While flower cluster spraying is more popular at present, whole plant spraying is often more effective for increasing the number and size of fruit.

The present report deals with further investigations on the use of hormone sprays on tomatoes grown in greenhouses and outdoors. It covers the following specific experiments: (a) Flower versus whole plant spraying with NOA and CIPA; (b) flower alone versus flower and fruit spraying with NOA and CIPA; (c) flower versus whole plant spraying with NOA and CIPA under commercial culture; (d) application of  $\beta$ -indolebutyric acid (IBA), CIPA, and IBA + CIPA in aerosol form to flowers; (e) flower cluster spraying with 2,5-dichlorobenzoic acid,  $\alpha$ -(o-chlorophenoxy) propionic acid and 2,4,5-trichlorophenoxypropionic acid; and (f) use of NOA and CIPA sprays on tomatoes grown outdoors.

The Master Marglobe variety was used in all experiments excepting (d) and (e), for which a strain of Break O'Day variety was employed. The cultural methods and greenhouse practices were the same as described elsewhere (1). Five clusters of fruit were allowed to set on the Marglobes and eight clusters on the Break O'Day plants. Each specific spray treatment, given once a week, was applied to duplicate groups of plants but sometimes in triplicate. The Marglobes were grown in 4-gallon crocks and the Break O'Day plants in ground beds as per accepted commercial practice described further on. Under greenhouse culture, where differences existed, the controls (untreated plants) were given a preferential exposure to light. Figures in the tables refer to an average per 10 plants. Included in the total of fruit harvested are also the "green" fruit gathered at the time of closing the respective tests, for undoubtedly they would have ripened had

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more time been allowed for their development. Only fruit of marketable size, above 85 grams in weight, were taken into consideration in yield records, though in most cases the number of small fruit, usually parthenocarpic, are also given.

#### FLOWER VERSUS WHOLE PLANT SPRAYING WITH $\beta$ -NAPHTHOXY-ACETIC (NOA) AND P-CHLOROPHENOXYACETIC (CIPA) ACIDS

Previous investigations had shown that whole plant spraying with growth substances often is just as satisfactory as flower spraying for induction of fruit setting of tomatoes grown under greenhouse conditions (1), and sometimes more so. It was deemed desirable to obtain additional evidence on this phase of our investigations. A winter crop of tomatoes was grown for this purpose. Hormone applications to these plants began on November 21 and continued until February 10. The weather was mostly cloudy until about March 1, and thereafter not very favorable for fruit setting.

Harvesting of the crop commenced on February 13 and continued until April 13. At the second gathering of the ripe and near ripe tomatoes it was observed that the whole plant sprayed and flower sprayed plants with CIPA had produced, on the average, larger fruit than plants in other groups, though some specimens were slightly abnormal in form.

Three weeks later (fourth harvest) there were gathered noticeably more large (marketable) fruit from all treated plants than from control ones. This difference continued more or less to the end of the experiment. Occasionally specimens of the CIPA treated groups, however, were somewhat pointed and a little softer than other tomatoes.

The results are presented in Table I. It will be noted that the most outstanding difference between treated and not treated plants was the conspicuous increase in number of fruit of marketable sizes and a corresponding decrease of small fruit, below 85 grams in weight. NOA as a whole plant spray and CIPA, applied either on flowers or plants, augmented the number of fruit per plant by 65 to 82 per cent. Since there was also an average increase in size of the fruit, the total weight of the marketable crop about doubled as a result of spraying with CIPA. Whole plant spraying with NOA was decidedly better than flower spraying with this material, while whole plant spraying with CIPA was slightly less effective than flower spraying with this very potent growth substance.

#### SPRAYING FLOWERS ALONE VERSUS FLOWER AND FRUIT SPRAYING WITH P-CHLOROPHENOXYACETIC ACID (CIPA)

When the whole plant is sprayed, not only the foliage but also the developing fruit receive the spray material several times. It was thought desirable to determine what effects, as regards fruit set and size, may be obtained from flower spraying alone and flower plus fruit spraying. A test of this sort should indicate whether from whole plant



TABLE I—EFFECTS OF FLOWER AND WHOLE PLANT SPRAYING WITH  $\beta$ -NAPHTHOXYACETIC (NOA) AND P-CHLOROPHENOXYACETIC (CIPA) ACIDS ON SET AND SIZE OF TOMATOES (SPRING CROP, 1945. AVERAGE PER TEN PLANTS)

Treatment (Flower or Whole Plant Spraying)	No. Fruit Har- vested	Increase in Num- ber of Market- able Fruit Due to Treatment (Per Cent)	Total Weight of Market- able Fruit (Grams)	Increase Due to Treat- ment (Per Cent)	Ave. Weight Per Mar- ketable Fruit (Grams)	Increase or De- crease Due to Treat- ment (Per Cent)
Controls	(a)** 90 (b) 204	—	11,401	—	126.7	—
NOA <sub>50</sub> *—flowers	(a) 104 (b) 204	+15.6	12,895	+13.1	124.0	-2.1
NOA <sub>100</sub> —whole plants	(a) 149 (b) 104	+65.5	19,686	+72.7	132.1	+4.3
CIPA <sub>100</sub> —flowers	(a) 164 (b) 49	+82.2	23,802	+108.8	145.1	+14.5
CIPA <sub>100</sub> —whole plant	(a) 159 (b) 86	+76.6	22,624	+98.4	142.3	+12.3

\*Subscript figures refer to parts per million of chemicals used.

\*\* (a) Above 85 grams in weight (marketable).

(b) Below 85 grams in weight (not marketable).

spraying the hormone exerts its influence through the foliage alone or also through the green fruit.

A group of Marglobe tomatoes was used for this study. Beginning on November 21 the first clusters of flowers were treated and thereafter, at weekly intervals, flowers either alone or with the developing fruit were sprayed with CIPA.

The records, given in Table II, seem to indicate that when as effective a growth substance as CIPA is applied to the fruits, in addition to the flowers, there was a slightly greater increase in yield, as ex-

TABLE II—EFFECTS OF P-CHLOROPHENOXYACETIC ACID (CIPA) SPRAYED ON FLOWERS ALONE AND ON FLOWERS AND FRUIT (SPRING CROP, 1945. YIELDS OF MARKETABLE FRUIT PER TEN PLANTS)

Treatment (Flower or Flower and Fruit Spraying)	No. Fruit Har- vested	Increase in Number of Fruit Due to Treatment (Per Cent)	Total Weight of Fruit (Grams)	Increase in Weight of Fruit Due to Treatment (Per Cent)	Ave. Weight Per Mar- ketable Fruit (Grams)	Increase Due to Treat- ment (Per Cent)
Controls .....	93	—	11,654	—	125.3	—
CIPA <sub>100</sub> *—flower spray ..	137	+47.3	18,800	+61.3	137.2	+9.5
CIPA <sub>100</sub> —flower and fruit spray .....	156	+67.7	21,311	+82.9	136.6	+9.0

\*See footnotes of Table I.

pressed by total weight of fruit. This was due chiefly to an augmented number of fruit set for improvement in size of the fruit from either treatment was about the same. One may conclude therefrom, that growth substances, when applied to the whole plant, exert their influence mainly through the foliage and only to a minor extent through the fruit.

FLOWER VERSUS WHOLE PLANT SPRAYING WITH  $\beta$ -NAPHTHOXYACETIC ACID (NOA) AND P-CHLOROPHENOXYACETIC ACID (CIPA) UNDER COMMERCIAL GREENHOUSE CONDITIONS.

An early spring crop of Break O'Day variety was grown for this purpose. The plants were set in a ground bed of good loam soil to which 4-12-4 fertilizer had been added at the rate of 1 ton per acre. In addition  $\text{NaNO}_3$  was supplied, as needed, to maintain a high soil nitrogen content during the growth period. Spacing was so arranged as to give about 4 square feet of ground area per plant. They were trained to a single stem and allowed to produce eight clusters of fruit, the tops being cut below the 9th flower cluster. Because of relatively close planting, in imitation of commercial practice, there was a heavy shading of the lower parts of the plants.

Spraying with growth substances was begun on November 21 and continued at weekly intervals until March 10. The crop was harvested between February 23 and May 15.

In Table III are presented the crop records of this experiment. The results indicate that, in general, whole plant spraying was more effective than flower spraying, as evidenced by the increased number of

TABLE III—EFFECTS OF FLOWER VERSUS WHOLE PLANT SPRAYING WITH  $\beta$ -NAPHTHOXYACETIC (NOA) AND P-CHLOROPHENOXYACETIC (CIPA) ACIDS (SPRING CROP OF BREAK O'DAY TOMATOES 1945. AVERAGE PER TEN PLANTS)

Treatments (Flower or Whole Plant Spraying)	No. Fruit Har- vested	Increase in Number of Marketable Fruit Due to Treat- ment (Per Cent)	Total Weight of Market- able Fruit (Grams)	Increase or Decrease in Weight of Fruit Due to Treatment (Per Cent)	Ave. Weight Per Mar- ketable Fruit (Grams)	Increase or De- crease Due to Treatment (Per Cent)
Controls	(a)* 144 (b) 63	—	23,796	—	165.2	—
NOA <sub>30</sub> —flowers	(a) 149 (b) 50	+3.5	24,796	+4.2	166.4	+0.7
NOA <sub>15</sub> —flowers	(a) 146 (b) 117	+1.5	21,121	-11.2	144.7	-12.4
NOA <sub>10</sub> —whole plant	(a) 205 (b) 78	+42.4	36,112	+51.8	176.2	+6.6
NOA <sub>30</sub> —whole plant..	(a) 205 (b) 25	+42.4	37,237	+56.5	181.6	+9.9
CIPA <sub>10</sub> —flowers	(a) 176 (b) 44	+22.2	30,934	+30.0	175.8	+6.4
CIPA <sub>1.25</sub> —whole plant	(a) 197 (b) 14	+36.8	41,666	+75.1	211.5	+28.0

\*See footnotes of Table I.

fruit set and the total weight of the crop. A part of the augmented weight was due to an increase in size but most of it to an increase in set.  $\beta$ -naphthoxyacetic acid at 20 parts per million as a whole plant spray increased the size of fruit but slightly over that produced by a concentration of 10 parts per million, but CIPA at  $1\frac{1}{4}$  ppm was a very potent material for size increase when the whole plant was

sprayed. In fact, CIPA, whether used on flowers or the whole plant, has the remarkable property of reducing the number of small fruit. In this respect it is just the opposite of  $\beta$ -indolebutyric acid. But it must be used with precaution and at a reduced concentration in cloudy weather to prevent occasional "puffiness" of the fruit. Para-chlorophenoxyacetic acid, like its more dangerous homologue, 2,4-D, stimulates to a marked extent the growth of the carpellary region of the fruit.

Judging from the records, as a flower spray NOA at 75 parts per million seemingly was too strong, under the prevailing environmental conditions, for the crop was reduced by 11.2 per cent, which was due almost entirely to a decreased size of the fruit. An unusually large number of small fruit matured on plants treated with NOA at 75 parts per million. At 50 parts per million NOA was only moderately effective as a flower spray on these Break O'Day tomatoes, but at 10 parts per million, as a whole plant spray, the set was increased 42.4 per cent and the yield 51.8 per cent.

#### APPLICATION OF $\beta$ -INDOLEBUTYRIC ACID (IBA), p-CHLOROPHENOXYACETIC ACID (CIPA), AND IBA + CIPA IN AEROSOL FORM TO FLOWERS

Ninety Break O'Day plants, grown similarly to those of the preceding group, were used for this test. The soil in the ground beds, where these plants were raised, was of very high fertility, as determined chemically, and therefore, an additional fertilizer application at the time of planting was not required. Nitrate of soda, however, was supplied as needed during the growth of these plants. Because of the position of the greenhouse, there was considerable shading which most probably reduced the yield.

The three aerosol preparations consisted of (a)  $\beta$ -indolebutyric acid .25 per cent + 20 ml cyclohexanone in dimethyl ether sufficient to make 400 grams of total mix; (b) Para-chlorophenoxyacetic acid .01 per cent in the same solvent and dispersion liquid; and (c) Para-chlorophenoxyacetic acid 400 milligrams +  $\beta$ -indolebutyric acid .960 grams (total .25 per cent) similarly dispersed. All preparations were held under pressure in small steel cylinders with proper nozzle attachment for release of the material in the form of a fine mist.

Application of the aerosols to open flowers was begun on November 21 and continued, at intervals of 1 week, until February 10, when the 8th or last flower cluster was fully open. There was some difficulty in securing release of a uniform amount of material through the nozzles. The crop was harvested as required, between February 14 and April 24.

The results, expressed on the basis of 10 plants, are presented in Table IV. It will be observed that, whether used alone or mixed with  $\beta$ -indolebutyric acid (IBA), p-chlorophenoxyacetic acid (CIPA) was effective in increasing the set, but even more in improving size of tomatoes. When IBA was used alone, in the form of aerosol, the set was reduced by 10.6 per cent while the size of the fruit was aug-

TABLE IV—EFFECTS OF  $\beta$ -INDOLEBUTYRIC ACID (IBA) ALONE, P-CHLOROPHOXYACETIC ACID (CIPA) ALONE, AND IBA + CIPA USED AS AEROSOL APPLICATIONS TO FLOWERS (SPRING CROP, 1945. AVERAGE PER TEN PLANTS)

Treatment	No. Fruit Harvested	Increase or Decrease in Number of Marketable Fruit Due to Treatment (Per Cent)	Total Weight of Marketable Fruit (Grams)	Increase or Decrease in Weight of Fruit Due to Treatment (Per Cent)	Ave. Weight Per Marketable Fruit (Grams)	Increase Due to Treatment (Per Cent)
Control....	(a)* 142 (b) 62	—	19,818	—	139.6	—
IBA**.....	(a) 127 (b) 84	-10.6	19,040	-3.9	149.9	+7.4
CIPA.....	(a) 154 (b) 44	+8.5	25,348	+27.9	164.6	+17.9
IBA + CIPA...	(a) 154 (b) 73	+8.5	24,460	+23.4	159.0	+13.9

\*See footnotes to Table I.

\*\*See page 258 for concentrations used.

mented by 7.4 per cent, and the total weight of the crop was depressed by 3.9 per cent because of the reduced set. It is worth emphasizing also that IBA, either alone or mixed with CIPA had a tendency to increase the number of small unmarketable fruit, while CIPA reduced their number in comparison with the amount on control plants.

These records, secured from aerosol applications, are quite in line with the results obtained repeatedly in our experiments when IBA or CIPA were applied in water sprays to tomato flowers. Due to the fact that special dispersion materials and more expensive equipment are required for aerosol preparations and application, their practical value is doubtful, certainly in the present stage of development.

#### FLOWER SPRAYING WITH 2,5-DICHLOROBENZOIC ( $\text{Cl}_2\text{B}$ ), $\alpha$ (O-CHLOROPHOXY) PROPIONIC (CIPP) AND 2,4,5-TRICHLOROPHOXYPROPIONIC ( $\text{Cl}_3\text{PP}$ ) ACIDS

A number of new substituted phenoxy and benzoic acids having been synthesized by Zimmerman and associates (3, 4, 5), who have found some of them highly potent for fruit setting of tomatoes, it was considered desirable to use three of these as flower sprays. The concentration of each substance used was determined on the basis of Zimmerman's experience<sup>2</sup> and were as follows:  $\text{Cl}_2\text{B}$  at 100 ppm, CIPP at 50 ppm and  $\text{Cl}_3\text{PP}$  at 10 ppm. These growth substances were sprayed by means of standard procedure once a week on Marglobe tomatoes, grown as an early spring crop. Period of treatment, November 21 to February 13.

During the progress of harvesting the crop, February 13 to April 13, it was observed that, because of a prolonged period of cloudy weather or for some other reason, an unusually large number of small fruit were developed on all plants, but especially those in the control

<sup>2</sup>Private correspondence with Dr. P. W. Zimmerman, November 6 and 8, 1944.

and Cl<sub>2</sub>B groups. Moreover, many of the large tomatoes were seedless, rough and to some extent hollow. This undoubtedly was due, in part at least, to the prevailing cloudy weather but probably also to a comparatively high concentration of the chemicals used under the existing environmental conditions.

As indicated by the records presented in Table V,  $\alpha$  (o-chlorophenoxy) propionic acid (CIPP) in particular, and to some extent also 2,4,5-trichlorophenoxypropionic acid (Cl<sub>3</sub>PP), at the concentrations

TABLE V—EFFECTS OF FLOWER SPRAYING WITH 2,5-DICHLOROBENZOIC ACID (Cl<sub>2</sub>B),  $\alpha$  (O-CHLOROPHENOXY) PROPIONIC ACID (CIPP) AND 2,4,5-TRICHLOROPHENOXYPROPIONIC ACID (Cl<sub>3</sub>PP) (AVERAGE PER TEN PLANTS)

Treatment	No. Fruit Harvested	Increase or Decrease in Number of Marketable Fruit Due to Treatment (Per Cent)	Total Weight of Marketable Fruit (Grams)	Increase or Decrease in Weight of Fruit Due to Treatment (Per Cent)	Ave. Weight Per Marketable Fruit (Grams)	Increase Due to Treatment (Per Cent)
Controls...	(a)* 129 (b) 165	—	16,709	—	129.5	—
Cl <sub>2</sub> B <sub>100</sub> ...	(a) 115 (b) 169	-10.8	15,834	-5.2	137.7	+6.3
CIPP <sub>50</sub> ...	(a) 156 (b) 68	+20.9	25,495	+52.6	163.4	+26.2
Cl <sub>3</sub> PP <sub>50</sub> ...	(a) 138 (b) 113	+7.0	20,756	+24.2	150.4	+16.1

\*See footnotes of Table I.

used, were far more effective than 2,4-dichlorobenzoic acid (Cl<sub>2</sub>B) in increasing set and size of the fruit. The reduction in number of small fruit (below 85 grams, and therefore unmarketable) by CIPP and Cl<sub>3</sub>PP is noteworthy.

#### USE OF $\beta$ -NAPHTHOXYACETIC ACID AND p-CHLOROPHENOXYACETIC ACID SPRAYS ON TOMATOES GROWN OUTDOORS

The object of this experiment was to test the possible value of  $\beta$ -naphthoxyacetic (NOA) and p-chlorophenoxyacetic (CIPA) acids as flower or whole plant sprays for tomatoes grown outdoors. A commercial strain of the Marglobe variety was raised for this purpose on a plot of heavily fertilized loam soil. To facilitate spraying, the plants were spaced widely, trained to a single stem and staked. Triplicate and quadruplicate rows of eight plants were used for each treatment.

Two synthetic growth substances were used at the following concentrations: NOA at 50, 75 and 100 parts per million for flower spraying and at 20 and 40 parts per million for whole plant spraying and CIPA at 10 and 20 parts per million for flower spraying. All applications were made once a week between June 16 and September 29. There was ample sunlight throughout the summer but a shortage of precipitation. Irrigation was required at times. Harvesting of the fruit extended between July 25 and October 12.

Though practically all of the hormone sprays used were within the effective range of concentration and some stronger, no significant improvement in yields was obtained from any of the applications. Size of the fruit, however, was increased somewhat, the maximum being about 15 per cent from plants sprayed with the highest concentration of either NOA or CIPA.

#### DISCUSSION AND SUMMARY

The present experiments, in addition to the one reported previously (1), verify and amplify the value of  $\beta$ -naphthoxyacetic (NOA) and *p*-chlorophenoxyacetic (CIPA) acids as "hormone" sprays for greenhouse-grown tomatoes. When used as a spray supplementary to pollination, CIPA has quite consistently given the greatest effect in increasing fruit set and size and, thereby, augmenting the total crop. The concentration of either substance, but especially of CIPA, must be adjusted according to the relative amount of light the plants are receiving. When used at too high a concentration during cloudy weather, when pollination takes place with difficulty, formative influences may occur due to excessive development of the pericarp in relation to placental tissue, resulting in production of occasional fruit that are to some extent abnormal in form. The greatest increase in yield, therefore, is associated with some danger of production of slightly "puffy" fruit unless care is taken in adjusting the concentration of CIPA to the prevailing environment, primarily light. For the undiscerning, therefore, NOA should be recommended in preference to CIPA.

Under commercial greenhouse conditions, whole plant spraying has been usually more effective than flower spraying, when applications are made once a week. Evidently these growth substances exert their catalytic potency not only directly on the flowers but also indirectly through the foliage and possibly the developing fruit. As a result of spraying the whole plant, the yield of Break o'Day tomatoes was increased 50 to 75 per cent and there was a striking reduction in number of small fruit. In this procedure the spray should be so directed as to avoid as much as possible the growing terminal part of the stem. This precaution will prevent possible undesirable formative effects on the leaves.

Of the three relatively new substituted benzoic and phenoxy acids that were tested,  $\alpha$  (o-chlorophenoxy)propionic acid at 50 parts per million showed considerable merit as a hormone spray for greenhouse-grown tomatoes. It is of interest to note here that this chemical was found an effective hormone also for string beans (2). Since the chlorophenoxypropionic acids have less pronounced formative influences than their acetic acid homologues, they should receive further attention as hormone sprays for tomatoes and possibly other plants.

When used in aerosol form,  $\beta$ -indolebutyric acid, at the specified concentration, was ineffective in increasing yield of tomatoes. Para-chlorophenoxyacetic acid, either alone or with indolebutyric acid, similarly applied, increased the set slightly, size of fruit considerably

and, therefore, the yield about 25 per cent. It is doubtful, however, whether in the present state of development, aerosol application of hormones is practicable because of the need for expensive equipment and rather complicated procedures for preparation of the material.

Large scale tests during three summers on the value of hormone sprays for tomatoes grown outdoors and well exposed to light have given consistently negative results. Neither  $\beta$ -naphthoxyacetic nor p-chlorophenoxyacetic acids, as flower or whole plant sprays, at various concentrations, has increased yields significantly. In some cases, though, the size of the fruit was augmented somewhat. Apparently under comparatively long days and more sunlight, during summer months, there is an abundant synthesis of naturally occurring hormones by the tomato plant, which may be conducive for maximal yield of fruit without the artificial stimulation by synthetic growth substances. We are obliged to conclude that hormone sprays are of no practical value for field cultivated tomatoes excepting possibly in regions or years of subnormal amount of sunlight.

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# The Effect of Pre-Packaging and Refrigeration of Strawberries on the Water Loss, Spoilage, Vitamin C Content, and Sugar-Acid Ratio of the Fruit<sup>1</sup>

By JAMES E. MOULTON, *Michigan State College,  
East Lansing, Mich.*

RECENT advances in the packaging and merchandising of certain fresh fruits and vegetables have made it possible to place on the market far more attractive and nutritious products than have been available heretofore. With our present methods of marketing strawberries, however, there is considerable loss in quality, as well as complete spoilage, by the time the fruit reaches the consumer. In an effort to improve this condition studies were made to determine the effect of various types of packages and methods of handling on the appearance, salability, and physiology of fresh strawberries. This report is concerned with the results of laboratory analyses run on the fruit during the course of these experiments.

## MATERIALS AND METHODS

Thirteen cases of Robinson strawberries for laboratory tests were delivered directly from the field to the Milburg Growers' Exchange in the afternoon of June 24, 1946. Upon arrival, the crates were immediately placed in cold storage at 40 degrees F. Part of the berries were in the conventional 16-quart wooden crate, while the remainder were in 1-quart paper boxes packed in 12-quart cardboard cartons. The Robinson variety of strawberry is now grown extensively in the southwestern part of Michigan. The berries ripen in midseason just slightly later than Premier. While they are characteristically large and firm, the season of 1946 was unusually warm and rainy the week preceding harvest resulting in fruit somewhat softer than normal.

The berries were cooled overnight and the following day one crate at a time was taken from the cold room and each quart box was either overwrapped (box entirely covered) or merely capped in either cellophane LST 350, pliofilm 75P6, or cellulose acetate. Some boxes were left unwrapped as a check on the various treatments. As soon as all of the boxes in a crate were wrapped, the latter was returned immediately to cold storage. The detailed information regarding the packaging schedule for the berries used in the laboratory tests is given in Table I.

In the evening the crates were loaded on a truck along with 100 pounds of ice, and the crates and ice were covered with blankets to

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keep the pack cool during the trip back to the laboratory. Upon arrival at the college, the berries were divided into two groups; one-half of each lot was placed in cold storage at 35 degrees F, while the other half remained in the laboratory where the temperature was 80 degrees F.

The next morning and every 24 hours thereafter until the end of the experiment, the gross weight and appearance of each box was recorded. The strawberries stored at 80 degrees F began to show considerable spoilage 3 days after picking, and at this time samples from each lot were analyzed for vitamin C, total acidity and total sugars. After the final gross weight determination at the end of the storage period, the berries in each box were graded and mold counts were made. In grading, the fruit in each quart was divided into three classes according to condition, and each group was weighed. Berries without any blemishes were placed in one class, those with some bad spots were placed in a second class, and the completely spoiled fruit went into a third class.

The berries held at 35 degrees F showed less spoilage and were stored 24 hours longer than those kept at 80 degrees F. These were then graded and assayed in the same manner as those stored at the higher temperature.

### RESULTS

*Water Loss:*—The various lots of strawberries stored at 80 degrees F all lost weight (Table I). The mean loss in weight, however, was

TABLE I—NUMBER OF MOLDY STRAWBERRIES AND WATER LOSS OF FRUIT AS AFFECTED BY VARIOUS CONTAINERS, FILMS AND WRAPS (STORAGE AT 35 DEGREES F FOR THREE DAYS OR AT 80 DEGREES F FOR TWO DAYS)

Number of Quarts Treated	Container	Film	Method of Wrap	Average Number of Moldy Berries Per Quart		Change in Weight of Fruit (Grams Per Quart)	
				35 Degrees F	80 Degrees F	35 Degrees F	80 Degrees F
12	Paper	Cellophane	Overwrap	2.6	15.6	+0.8	-3.7
12	Paper	Pliofilm	Overwrap	5.4	19.2	+0.3	-1.0
12	Paper	Cellophane	Cap	7.2	11.2	-0.8	-7.5
12	Paper	Pliofilm	Cap	5.6	18.2	-1.0	-7.0
12	Paper	None	None	6.2	12.2	-1.2	-12.7
16	Wood	Cellophane	Overwrap	5.3	18.5	+0.5	-4.0
16	Wood	Pliofilm	Overwrap	7.0	17.8	+0.1	-2.5
16	Wood	Cellophane	Cap	4.4	17.8	-1.5	-8.7
16	Wood	Pliofilm	Cap	1.2	16.3	-1.5	-8.0
16	Wood	None	None	4.7	29.3	-4.2	-15.8
8	Wood	Cellulose acetate	Overwrap	5.5	9.0	-2.8	-8.5
8	Paper	Cellulose acetate	Overwrap	3.3	11.5	-1.8	-4.5
8	Wood	Cellulose acetate	Cap	—	12.0	—	-11.0
6	Paper	Cellulose acetate	Cap	6.0	23.0	—	-15.5
6	Special paper	Cellulose acetate	Overwrap	4.0	14.0	+0.7	-8.0
6	Special paper	Cellulose acetate	Cap	4.5	7.3	—	-10.0
Average—all quarts.....				4.9	17.0	-0.9	-7.1

not the same for the different treatments. Where no wrap at all was used, the average loss in weight was 14.2 grams per box or 2.2 per cent (Table II). There was less loss of moisture when the boxes were entirely wrapped with any given film than when a cap of the same material was applied. With the pliofilm overwrap the loss was 1.8

TABLE II—THE EFFECT OF FILMS AND WRAPS ON MOISTURE LOSS FROM STRAWBERRIES HELD FOR TWO DAYS AT 80 DEGREES F

Treatment	Average Loss in Weight of Fruit	
	Grams Per Quart	Per Cent
Pliofilm overwrap.....	1.8	0.3
Pliofilm cap.....	7.5	1.2
Cellophane overwrap.....	3.9	0.6
Cellophane cap.....	7.1	1.0
Cellulose acetate overwrap.....	8.2	1.3
Cellulose acetate cap.....	12.3	1.9
No wrap.....	14.2	2.2

- grams per box (0.3 per cent) as compared with a loss of 7.5 grams (1.2 per cent) when this material was used as a cap. The cellophane overwrapped packages lost 3.9 grams per box (0.6 per cent), whereas those with a cap of the same film lost 7.1 grams (1.0 per cent). Cellulose acetate was the most porous of the three films applied, and, as a result, the packages overwrapped with this material lost more moisture than those overwrapped with the other films. The overwrapped boxes lost 8.2 grams (1.3 per cent), and the capped boxes lost 12.3 grams (1.9 per cent) in this instance. The packages overwrapped in the relatively impermeable pliofilm lost the least water in these tests, while the somewhat more porous cellophane was next in rank in this respect.

In contrast to the loss in moisture of the fruit stored at 80 degrees, the berries in cold storage, in most case, lost weight very slightly and some of the lots even showed a tendency to gain. The average loss in weight of all the different lots stored at 35 degrees F was only 0.9 grams (0.1 per cent) compared to a loss of 7.1 grams (1.0 per cent) when the berries were held at 80 degrees F. The lots which increased in weight in every instance contained the overwrapped packages. When the boxes were entirely wrapped with a film there was some condensation of moisture on the film, especially where pliofilm was used.

Loss in weight was little if at all affected by the material of which the boxes were made.

*Spoilage*.—At the end of the storage period the berries were examined and divided into three classes as explained in the section on materials and methods. There seemed to be little relationship between the type of film or the type of box used and the amount of spoilage or the number of moldy berries observed (Tables I and III).

There was, however, a highly significant difference in the amount of spoilage between lots of fruit stored at 35 degrees F and at 80 degrees F. For example, the mean weight of the berries with no bad spots was 365 grams per box when held at the lower temperature, whereas the mean was 171 grams following storage at the higher temperature. In the third class, containing completely spoiled fruit, the mean was only 56 grams after cold storage for 3 days, while it was 129 grams following storage at 80 degrees F for 2 days.

Not only were there fewer spoiled berries, but also fewer moldy berries under refrigeration than at room temperature. The average number of moldy berries per box was 17 at 80 degrees F and 4.9 at 35 degrees F (Table I).

TABLE III—SPOILAGE IN STRAWBERRIES AS AFFECTED BY VARIOUS CONTAINERS, FILMS AND WRAPS (STORAGE AT 35 DEGREES F FOR THREE DAYS OR AT 80 DEGREES F FOR TWO DAYS)

Container	Film	Method of Wrap	Average Weight of Fruit (Grams Per Quart)					
			With No Bad Spots		With Some Bad Spots		Completely Spoiled	
			35 Degrees F	80 Degrees F	35 Degrees F	80 Degrees F	35 Degrees F	80 Degrees F
Paper.....	Cellophane	O-erwrap	432	238	203	232	34	145
Paper.....	Pliofilm	Overwrap	385	235	239	185	56	131
Paper.....	Cellophane	Cap	474	384	171	158	62	65
Paper.....	Pliofilm	Cap	378	95	243	261	76	202
Paper.....	None	None	368	175	259	271	56	148
Wood.....	Cellophane	Overwrap	241	105	307	197	70	155
Wood.....	Pliofilm	Overwrap	312	139	255	228	80	74
Wood.....	Cellophane	Cap	319	135	261	172	44	133
Wood.....	Pliofilm	Cap	389	178	186	217	37	90
Wood.....	None	None	350	—	216	—	46	—
Wood.....	Cellulose acetate	Overwrap	366	—	211	—	58	—
Paper.....	Cellulose acetate	Overwrap	387	135	181	270	39	120
Wood.....	Cellulose acetate	Cap	—	202	—	164	—	152
Paper.....	Cellulose acetate	Cap	373	108	204	200	84	67
Special paper.	Cellulose acetate	Overwrap	504	365	129	159	26	73
Special paper.	Cellulose acetate	Cap	430	197	208	292	54	153
Average—all quarts.....			365	171	228	221	56	129

*Vitamin C*:—The chemical determinations for ascorbic acid (Vitamin C) were made by the method of Morell (2) as modified by Lucas (1). This method is essentially the oxidation of ascorbic acid quantitatively with 2,6-dichlorophenolindophenol. Boxes of berries were drawn at random from each lot stored at 80 degrees F, and 50 gram samples of each were homogenized in a Waring blender containing 200 cc of 2 per cent metaphosphoric acid. The liquid was then filtered and titrated.

The ascorbic acid content of the strawberries was high even after storage at 80 degrees F (Table IV). The mean Vitamin C content of all 12 samples was 86 milligrams per hundred grams of fresh material. Slate and Robinson (3) recently analyzed 37 varieties of strawberries for ascorbic acid and obtained a mean of 62 milligrams per 100 grams of fruit. Catskill with a mean of 81 milligrams per 100 grams had the highest vitamin content of the group. Even this is a somewhat lower average than was obtained in the present studies with the Robinson variety. Since no other varieties were tested at the same time, it is not possible to say whether it was the growing conditions or the variety of berry that was responsible for the relatively high vitamin readings obtained in these tests. There was no correlation between the ascorbic acid content and the type of container or the kind of wrap applied.

Ascorbic acid tests on berries assayed following storage at 35 degrees F gave an average of 85 milligrams of the acid per hundred grams of fresh fruit. The storage temperature had no effect upon the Vitamin C level of the fruit.

*Total Acidity and Sugars*:—Samples from the lots stored at 80 degrees F and at 35 degrees F each gave a mean total acidity reading of

TABLE IV—VITAMIN C CONTENT (MILLIGRAMS PER 100 GRAMS OF FRESH FRUIT), TOTAL SUGARS AND TOTAL ACIDITY OF STRAWBERRIES AS AFFECTED BY VARIOUS CONTAINERS, FILMS AND WRAPS (STORAGE AT 35 DEGREES F FOR THREE DAYS OR AT 80 DEGREES F FOR TWO DAYS)

Container	Film	Method of Wrap	Vitamin C Content of Berries	Total Sugar (Per Cent)		Total Acidity (ml N/10 Acid Per Gram)	
				35 Degrees F	80 Degrees F	35 Degrees F	80 Degrees F
Paper.....	Cellophane	Overwrap	93	3.58	3.42	1.81	1.23
Paper.....	Pliofilm	Overwrap	91	4.06	4.27	1.14	1.25
Paper.....	Cellophane	Cap	80	4.04	3.44	1.12	1.16
Paper.....	Pliofilm	Cap	70	3.91	3.94	1.38	1.18
Paper.....	None	None	75	3.35	3.66	1.34	1.12
Wood.....	Cellophane	Overwrap	85	4.66	4.76	1.17	1.16
Wood.....	Pliofilm	Overwrap	90	4.60	3.76	1.25	1.16
Wood.....	Cellophane	Cap	100	4.58	4.37	1.19	1.31
Wood.....	Pliofilm	Cap	83	4.27	3.93	1.29	1.30
Wood.....	None	None	88	4.35	4.31	1.17	1.38
Wood.....	Cellulose acetate	Overwrap	90	—	4.33	—	1.37
Paper.....	Cellulose acetate	Overwrap	85	5.38	—	1.33	—
Wood.....	Cellulose acetate	Cap	—	—	4.17	—	1.21
Paper.....	Cellulose acetate	Cap	—	—	—	—	—
Special paper.	Cellulose acetate	Overwrap	—	3.89	—	1.15	—
Special paper.	Cellulose acetate	Cap	—	—	—	—	—
Average—all quarts.....			86	4.3	4.0	1.24	1.24

1.24 milliliters of N/10 acid per gram (Table IV).<sup>2</sup> No differences of significance between lots were observed.

The sugars were extracted with 95 per cent ethyl alcohol in a Waring blender and the evaluation was according to the procedure in Methods of Analysis, A. O. A. C., Fifth Edition.

Refrigerated berries had an average total sugar content of 4.3 per cent, while the berries kept in the laboratory yielded 4.0 per cent sugar. No differences of significance between lots were found.

*Color Change and Appearance:*—No accurate color determinations were made. It was observed, however, that the berries in cold storage became darker and duller in appearance than those at 80 degrees F. The berries packaged in a pliofilm overwrap were the least attractive of all after prolonged cold storage because they became dark in color and wet from the moisture condensing within the package. The boxes with the porous cellulose acetate caps and overwraps were very attractive because the film is clear and there was no tendency to fog over with changes in temperature.

## CONCLUSIONS

The appearance of the strawberries was improved by the use of a cap or an overwrap of any one of the three films employed in these tests, except where water condensed on the film. In addition to improving the appearance of the strawberries, the wrapper prevents the customer from pouring the berries from the box for examination, and it keeps the fruit clean. Loss of moisture is decreased by the use of a relatively impermeable film like pliofilm, but temperature changes

<sup>2</sup>Chemical analyses for sugar and acidity were made by Dr. E. J. Benne, Mrs. Dorothy Waldron, and Dr. Gloria Manalo, Department of Agricultural Chemistry, Michigan State College.

cause the condensation of moisture within packages wrapped in this way. This moisture in turn favors softening and darkening of the fruit, and the use of impermeable wrappers may not be desirable for this reason. Where conditions favor fogging of the film, the use of a material quite permeable to water, such as cellulose acetate, was found to be the most satisfactory.

The quality of the fruit as indicated by spoilage, mold counts, the vitamin C level, or sugar-acid analyses was not appreciably affected by the type of film used, the method of wrapping the package or the material of which the box was made.

Refrigeration materially increased the length of time the strawberries could be stored. At 35 degrees F, moisture loss was low, and the color of the berries became somewhat darker than normal under prolonged storage. Spoilage and molding of the berries was also significantly reduced as compared with fruit stored at 80 degrees F. No other effects of cold storage were detected.

The pliable cardboard box is more difficult to handle than the more rigid wooden container. It is likely to bulge and so hold more than a standard quart of berries.

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# Ascorbic Acid Content and Sugar-Acid Ratios of Fresh Fruit and Processed Juice of Tomato Varieties<sup>1</sup>

By L. E. SCOTT<sup>2</sup> and E. P. WALLS, *Maryland Agricultural  
Experiment Station, College Park, Md.*

IN connection with 1946 tomato variety trials at the Maryland Experiment Station certain analyses of the fresh fruit and processed juice were obtained to assist in the evaluation of the several varieties for juice manufacture. Data on the ascorbic acid levels of processed tomato juice are of particular interest at this time in view of the standards which have been tentatively proposed by the American Medical Association (5). Sugar and acidity determinations were made to determine the possible utilization of these factors as objective tests of quality.

No attempt is made here to review the extensive literature on the nutritive value of the tomato. The reader is referred to the excellent review of Hamner and Maynard (3) published in 1942. The analyses of Bohart (1) are particularly pertinent for comparison with the results given in the present paper. A great many ascorbic acid analyses of tomato varieties and tomato products have been conducted during the last few years under the National Cooperative Project on "Conservation of Nutritive Value of Foods" but as yet these data have not been made available generally.

## METHODS

The tomatoes for analysis and for preparation of the juice samples were obtained from plants raised from seed sown in the greenhouse and grown at the University Plant Research Farm. The experimental fruits were harvested near the middle of the harvest season from plants which had vigorous, healthy foliage. The fruit was red ripe at the time of picking and was allowed to remain in the laboratory overnight at room temperatures before analyses and processing were carried out.

The juice was prepared by washing the tomatoes, heating them in live steam for 3 minutes, and extracting the juice in a laboratory model extractor. The raw juice was heated to 190 degrees F in an open jacketed steam kettle before filling into No. 1 Picnic cans which were processed in boiling water for 27 minutes. After cooling in running tap water, the cans were stored at room temperature until analyzed.

Representative, homogenous samples for analysis were obtained by cutting wedge shaped sections from duplicate lots of eight fruits. For the ascorbic acid determinations about 75 grams of such sections were blended with exactly twice as much 0.5 per cent oxalic acid for 3 minutes in a Waring blender. An aliquot of the supernatant liquid after centrifuging was titrated visually with standardized dichlorophenol-

<sup>1</sup>Scientific Paper No. A161, Contribution No. 2056, of the Maryland Agricultural Experiment Station, Department of Horticulture.

<sup>2</sup>With the technical assistance of Mary Smith.

dophenol dye. Another lot of sections weighing about 200 grams was macerated in the blender to prepare a homogenous sample for sugar, pH, and total acidity determinations. For the sugar analysis 10 grams of the blend was extracted by refluxing for 10 minutes in alcohol adjusted to 80 per cent concentration. Invert sugar was estimated by the Shaffer-Somogyi method as given by Heinze and Murneek (4). Hydrolysis of several samples for total sugar analyses showed that practically all of the sugars present were in the invert form. The pH of an aliquot of the blend was read with a MacBeth pH meter, while the total acidity was determined on the same sample by direct titration with standard NaOH to pH 7.

Ascorbic acid of the juice was determined on samples blended for 2 minutes with two parts of 0.5 per cent oxalic acid to one part juice. Other analyses of the juice were made in the manner given for the fresh fruit but without the use of the blender. Duplicate cans of juice were used for all determinations.

### RESULTS

*Ascorbic Acid Content:*—Ascorbic acid values for the fresh fruits ranged from 17.1 to 25.1 milligrams per 100 grams with an average of 22.7 milligrams for the 11 varieties (Table I). Analysis of the raw

TABLE I—ASCORBIC ACID CONTENT OF FRUIT AND JUICE  
OF ELEVEN VARIETIES OF TOMATOES\*

Variety	Mg of Ascorbic Acid in 100 Gm of:			
	Fresh Fruit	Raw Juice	Juice Stored 1 Week	Juice Stored 8 Weeks
Garden State.....	23.6	23.3	21.8	21.2
Master Marglobe.....	25.1	22.7	21.5	19.6
Pan America.....	24.8	22.4	20.4	19.2
Rutgers.....	24.4	24.8	23.1	21.5
Stokesdale.....	20.3	22.0	19.3	18.0
Valiant.....	24.4	24.0	20.8	19.0
Wisconsin 55.....	24.3	20.6	19.0	17.5
178 A.....	17.1	18.9	19.0	17.7
178 B.....	19.3	21.6	20.4	19.1
378.....	24.4	24.8	21.1	20.4
409.....	21.7	20.8	19.2	18.0
Average of 11 varieties.....	22.7	22.4	20.5	19.2

\*Seed of numbered varieties were obtained from Campbell Soup Company.

juice made immediately after extraction gave ascorbic acid values of about the same order as those of the fresh fruit. Processed juice stored for 1 week contained from 19.0 to 23.1 with an average of 20.5 milligrams. After 8 weeks storage at approximately 70 degrees F the average ascorbic acid content decreased to 19.2 milligrams. Only three juice values were above 20 milligrams; those of Garden State, Rutgers, and No. 378. The ascorbic acid content of the stored juice was 84.6 per cent that of the fresh fruit and 85.7 per cent that of the raw juice analyzed immediately after extraction. There were no outstand-

ing differences among varieties in the percentage loss of ascorbic acid during processing, nor were there great differences in the values found in the fresh fruit or juices of the several varieties. Varietal differences shown are probably only slightly above sampling error and would certainly not form a basis for selection of any one of the varieties for the manufacture of juice of high ascorbic acid content.

It is evident that the ascorbic acid level of the raw fruit of many of the varieties was not sufficiently high for manufacture of juice with an ascorbic acid content (after 8 weeks storage) above 20 milligrams per 100 grams, which is the level proposed for the "Seal of Acceptance" rating by the American Medical Association (5). The retention percentages obtained in the present work are in line with optimum retention figures given by Clifcorn and Peterson (2) for efficient commercial processes.

Ascorbic acid analyses of raw fruit of a number of varieties grown in the Eastern and Middle Western States (from the National Co-operative Project Reports) show that of 163 analyses only 75, or less than half, were above the 20 milligrams per 100 gram level.

*Total Acidity and pH*.—Total acidity, expressed as citric acid, of the fresh fruits of the 11 varieties ranged from .273 to .416 per cent (Table II). Acidity of the processed juice was invariably higher than

TABLE II—TOTAL ACIDITY, PH, SUGAR CONTENT, AND SUGAR/ACID RATIOS OF THE FRESH FRUIT AND PROCESSED JUICE OF 11 VARIETIES OF TOMATOES†

Variety	Fresh Fruit				Juice Stored 1 Week				Juice Stored 8 Weeks			
	pH	Total Acidity*	Per Cent Sugar**	Sugar/Acid Ratio	pH	Total Acidity	Per Cent Sugar	Sugar/Acid Ratio	pH	Total Acidity	Per Cent Sugar	Sugar/Acid Ratio
Garden State	4.4	0.331	3.58	10.8	4.2	0.418	3.58	8.6	4.1	0.388	3.06	7.9
Master Marglobe	4.3	0.397	3.10	7.8	4.0	0.512	2.98	5.8	4.1	0.491	2.78	5.7
Pan American	4.2	0.409	3.08	7.5	3.9	0.517	2.68	5.2	4.0	0.495	2.32	4.7
Rutgers	4.4	0.342	2.69	7.8	4.1	0.461	3.15	6.8	4.1	0.442	2.83	6.4
Stokesdale	4.3	0.389	2.70	6.9	4.0	0.477	2.28	4.8	4.2	0.449	2.12	4.7
Valiant	4.3	0.345	2.88	8.3	4.0	0.440	2.55	5.8	4.1	0.433	2.27	5.2
Wisconsin No. 55	4.3	0.416	2.93	7.0	4.0	0.537	2.45	4.6	4.1	0.517	2.18	4.2
178 A	4.4	0.327	2.80	8.6	4.2	0.381	3.23	8.5	4.2	0.352	2.78	7.5
178 B	4.4	0.273	2.90	10.6	4.2	0.384	3.15	8.2	4.2	0.357	2.98	8.3
378	4.5	0.285	3.05	10.7	4.1	0.508	2.95	5.8	4.2	0.488	2.68	5.5
409	4.5	0.306	2.88	9.4	4.1	0.376	2.78	7.4	4.1	0.434	2.77	6.4

\*Total acidity expressed as per cent citric acid on fresh weight basis.

\*\*Sugar content expressed as per cent invert sugars on fresh weight basis.

†Seed numbered varieties were obtained from Campbell Soup Company.

that of the fresh fruits, ranging from .376 to .537 per cent in the juice after 1 week storage. Acidity of the juice tended to decrease slightly during storage so that at the end of 8 weeks, acidity values ranged from .352 to .517 per cent. Relative acidity of the different varieties remained in about the same order in the fresh fruits and in the two lots of juice. Wisconsin No. 55, Master Marglobe, Pan America, and No. 378 showed the highest acidity in the juice. No. 178 A, 178 B, and Garden State were of the lowest acidity of the 11 varieties.



The pH values were in the same order as the total acidity readings, ranging from 4.2 to 4.5 in the fresh fruit and from 3.9 to 4.2 in the processed juice.

*Sugar Content and Sugar-Acid Ratios:*—The sugar content of the fresh fruit and the freshly prepared juice was about the same, ranging from 2.28 to 3.58 per cent (Table II). Sugar content of the juice decreased slightly during storage in all varieties, with values ranging from 2.12 to 3.06 after 8 weeks storage. In general the sugar content was inversely correlated with total acidity so that the calculated sugar-acid ratios show wider variation among varieties than either sugar content or acidity. In the fresh fruit, sugar-acid ratios ranged from 6.9 in Stokesdale to 10.8 in Garden State. Lower ratios were found in the freshly prepared juice, ranging from 4.6 in Wisconsin 55 to 8.6 in Garden State. There was a further slight decrease in the ratios during the 8 week storage period.

It was found that the sugar-acid ratios of the juices were in close agreement with organoleptic ratings of blandness and acidity. Juices with high sugar-acid ratios were bland, lacked sharpness in taste, and had a tendency to be "flat". Juice of Garden State, No. 178 A, and No. 178 B were in this category with sugar-acid ratios of 7.9, 7.5, and 8.3 respectively. On the other hand juices with low ratios, such as Wisconsin No. 55 (4.2 ratio), Stokesdale (4.7 ratio) and Pan America (4.7 ratio) were sharp and acid. Observation after longer periods of storage have indicated a noticeable change in organoleptic ratings of the juices. Data on sugar-acid ratios together with ascorbic acid retention values of the juices after storage will be presented in a later paper.

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## The Effect of Planting Design Upon the Amount of Seed Produced by Male-Sterile Tomato Plants as a Result of Natural Cross-Pollination

By CHARLES M. RICK, *University of California, Davis, Calif.*

IF a genetically male-sterile plant never produces functional pollen, any seeds that it yields must result from cross-pollination. The seeds yielded by male-sterile plants under field conditions, therefore, provide a measure of the amount of natural cross-pollination. The setting of seeds by male-sterile tomato plants probably cannot be taken at face value to indicate the amount of natural cross-pollination expected of male-fertile plants, because any viable pollen transferred to the stigma of a male-sterile tomato flower is likely to function; whereas only a fraction of the viable pollen transferred to the stigma of a male-fertile flower would be likely to function in competition with the abundant pollen that normally migrates from anthers to stigma of the same flower in the self-pollinating mechanism of the tomato. The quantity of pollen transferred from other plants to flowers of either type should be similar, however, and the number of seeds set by male-sterile plants should suggest the relative amount of natural cross-pollination occurring in fertile tomato plants. The use of male-sterile plants in such tests also provides information that might reveal improved techniques for the production of  $F_1$  hybrid tomato seed.

### PRELIMINARY FINDINGS

Male-sterile tomato plants have been utilized in exploratory tests to determine what effect certain variables might have upon the amount of natural cross-pollination. These preliminary plantings have revealed a profound influence of the variety of fertile pollen parent used, ecological factors at different stations (primarily differences in kind and numbers of insect vectors), and planting arrangement.

The preliminary plantings were of three types described briefly as follows:

*Series A:*—In a single planting at Davis, California, one row of male-sterile plants was located between two rows of male-fertile plants. Included were two male-sterile mutants —  $ms_2$  Pearson and  $ms_3$  San Marzano — and four different fertile varieties, the varieties being arranged factorially so that plants of each of the two sterile varieties were associated in all combinations with each of the four fertile varieties.

*Series B:*—A single row of  $ms_3$  San Marzano was planted between two rows of fertile San Marzano in this series. Plantings of this type were made in four different localities.

*Series C:*—At one end of the Series B planting a single plant of the  $ms_3$  mutant was surrounded by eight fertile plants of San Marzano. This arrangement was also planted in four different localities. Growth was good in all series, the branches of adjacent plants in-

termingling by the middle of the season in all varieties except Pearson, which, because of its determinate habit, often touched adjacent plants, but seldom mingled with them.

Attention will be directed only to the effect wrought by proximity of the fertile and sterile branches upon the fruit-setting ability of the male-sterile flowers. It was found that the fraction of fruit set during any part of the entire flowering season could be satisfactorily measured by examining the inflorescences produced throughout the length of representative branches. The pedicel of a flower that abscisses without setting a fruit remains as a slender stub and is easily distinguished from the greatly enlarged one that has borne a fruit, even if the fruit abscisses in early development.

The fruit-setting performance of four branches from each male-sterile plant was recorded in this manner, one branch from each quadrant of the plant, thereby including two branches that grew toward adjacent plants in the same row, and two that grew toward adjacent plants in flanking rows. In Series A and B a pair of branches that grew toward other male-sterile plants would thereby be compared with a pair that were directed toward fertile plants. Series C served as a check, since branches in all four quadrants grew toward fertile plants.

The total number of flowers on a branch and the number that produced fruit were recorded. Since the branches being compared yielded approximately the same number of flowers, the statistical comparison is based only on the total number of fruits produced by each branch. For each plant, the total fruit yield of the two branches growing parallel with the row is compared with the total of the two growing at right angles to the row. The number of fruits set on each pair of branches was low (18 or less) and should vary according to the Poisson distribution, aside from heterogeneity arising from plant and branch differences. Since the variance equals the mean in a Poisson distribution, the yields cannot be correctly analyzed unless transformed to some function that is independent of the mean. Analysis of variance was therefore applied to Bartlett's (1) transformation,  $\sqrt{x + 0.5}$ ,  $x$  being the observed number. Table I presents a summary of this analysis.

TABLE I—ANALYSIS OF NUMBERS OF FRUITS SET ON: (A) BRANCHES OF MALE-STERILE PLANTS THAT GREW TOWARD FERTILE PLANTS, AND (B) THOSE THAT GREW TOWARD MALE-STERILE PLANTS

	Series A†	Series B†	Series C†
Number of plants.....	23	10	4
Mean number of fruits per branch growing:			
(a) at right angles to the row ( <i>i.e.</i> , toward fertile plants in all series).....	3.28	3.10	3.8
(b) parallel with the row ( <i>i.e.</i> , toward male-sterile plants in Series A and B, and fertile plants in Series C).....	1.67	0.80	2.7
Variance:			
Between branches.....	5.29**	5.20*	0.360
Between plants.....	0.927	0.449	0.593
Error.....	0.298	0.622	0.230

†Series designation is explained in text.

\*F value is significant at the 0.05 level.

\*\*F value is significant at the 0.01 level.

In both Series A and Series B the branches of male-sterile plants that grew toward fertile plants (at right angles to the row) produced significantly more fruits than the branches that grew toward other sterile plants (parallel with the row). The former were twice as productive in Series A, and nearly four times as productive in Series B. This effect was less extreme in the Pearson mutant than in San Marzano and is probably related to the difference in intermingling occasioned by the difference in plant habit of these two varieties. This varietal difference might explain why differences in branch yields were greater in Series B than in Series A. The branches of Series C that grew at right angles to the row also produced more fruit than those running parallel with the row, but the difference is of a smaller order, and the  $F$  value of this difference, 1.5, falls far short of the 10.1 required for significance at the 5 per cent level. Since Series C plantings were made contiguous to those of Series B with identical row directions, these results indicate that pollen production of the plant toward which the branch grew is responsible for the difference in the amount of natural cross-pollination, and eliminates other factors that might be associated with orientation of the plantings.

Currence and Jenkins (3) tested the amount of natural cross-pollination in fertile tomatoes as determined by the proportion of hybrids in the progeny of plants that differed in genetic seedling characters. They found that the rate of crossing is greatly affected by the distance between plants, the rate being highest in plants spaced 6 feet apart—the closest distance tested—and decreasing rapidly with increased distance between plants. In effect, the results of the present tests substantiate these findings, demonstrating further increases in cross-pollination as the distance is decreased to intervals shorter than 6 feet. These results are also in agreement with the observed habits of the native solitary bees that are responsible for the transfer of tomato pollen in California. These vectors have been observed at Davis to collect pollen from flowers in a very small area before returning to their nest or before flying to other plants at a considerable distance.

#### DESIGN OF THE TEST PLANTING

The initial experience suggested that the amount of seed produced by natural cross-pollination in tomatoes might be modified if the pollen and seed parents were planted in different arrangements. Accordingly, fertile and male-sterile plants were arranged in three designs, which provided extreme differences in the amount of contact between the two plant types.

Fig. 1 is a diagram of the three planting arrangements used in this test. Equal numbers of fertile (F) and male-sterile (S) plants were placed in a simple geometric pattern in each treatment. Treatment 1 consists of squares of four-sterile plants alternating with squares of four fertile plants in a checkerboard arrangement. Of the four plants that are closest to any sterile plant—that is, the adjacent plants in the same row and those in the flanking rows—two are fertile and two are sterile. The next closest group of four—the plants situated

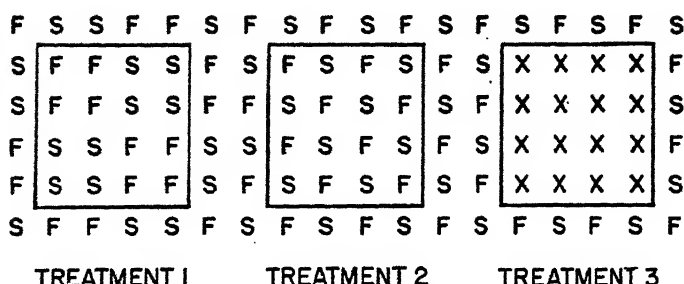


FIG. 1. Diagram of planting designs. F represents a fertile plant; S, a male-sterile plant; and X, the paired planting of a fertile and a male-sterile plant.

diagonally with respect to rows — also include two fertile and two sterile plants. This treatment provides the least contact between fertile and sterile plants. Treatment 2 is a checkerboard arrangement of single fertile and sterile plants. Here the four plants closest to a sterile plant are all fertile; whereas the next four surrounding plants are all sterile. In treatment 3 — an interesting arrangement suggested by Dr. J. W. Lesley — a fertile and a sterile plant were placed together in each of the 16 positions within the plot. Actually, the members of a pair (X) were set about 6 inches apart in order to allow the plants to establish themselves without immediate competition after transplanting. Branches of these paired plants invaded each other to a large extent, providing the greatest degree of intermingling of fertile and sterile branches of the three treatments.

Each of the three treatments was replicated three times in a 3 by 3 Latin square. Adjoining plots were separated by two guard rows, and a single guard row surrounded the entire planting. Excepting treatment 3, the planting arrangement used within a plot was also maintained in the guard row surrounding the plot. In this way it was possible to include exactly the same number of sterile plants as fertile ones in the whole planting. The planting was located in the center of a large vacant area. A much larger planting of tomatoes lay 100 feet to the south of this test planting. The observations give no evidence of influence by surrounding plantings.

It was considered desirable to use fertile and sterile plants of the same variety for this experiment, yet some device was needed for distinguishing fruits of the two types wherever their branches intermeshed. This requirement was satisfied by mutants that had previously been discovered in the variety Pearson. The *ms<sub>2</sub>* gene is ideal for this purpose because it renders the homozygote wholly pollen sterile, as demonstrated by a test to be described subsequently, yet it does not impair fertility of the ovules (8). Except for the inherited male sterility, this line is indistinguishable from the variety Pearson. Pollard and Peterson's (7) use of yellow-fruited varieties in guard rows of tomato yield plots suggested a means of identifying fruits of the two parents. A yellow-fleshed mutant of Pearson satisfied this

requirement, and served advantageously as the pollen parent in this experiment. The original plant of this line was discovered by virtue of its fruit color in a large commercial field of Pearson. On self-pollination this mutant reproduces itself without variation. Since hybrids between it and the standard *rr* yellow-fleshed stock are also yellow-fleshed, this mutant must also carry the *r* gene or a very similar allele. This mutant resembles Pearson in all other respects and probably represents a second mutation at this locus instead of a recombination product from a chance outcross between Pearson and a yellow-fruited variety. The fruits set on the male-sterile plants could consequently be distinguished by their difference in color from those of the fertile plants.

The use of male-sterile plants to measure natural cross-pollination as in this test is based on one very important assumption, — namely, that the homozygous male-sterile plants never produce pollen that can function in self-pollination. This assumption was tested as a necessary adjunct to the experiment. Five plants of the *ms<sub>2</sub>* mutant were planted together with other male-sterile mutants in a group that was isolated at least 1,000 yards from any other tomatoes. This planting was made under conditions very similar to those of the main experimental planting, but was situated about 1 mile from it. These five plants grew to very large size, characteristic of unfruitful tomatoes. At the end of the season the total flower number was ascertained by counting the pedicels in the method previously described. The five plants had produced a total of 5,947 flowers of which 350 had set fruit. All of the fruits were found to be parthenocarpic. Since no seeds whatever were produced by these isolated male-sterile plants growing under conditions otherwise similar to those of the experiment, it can be safely assumed that seeds set by the *ms<sub>2</sub>* individuals in the main test planting were derived from cross-pollination.

Plants used in this experiment were started from early sowings in the greenhouse. The male-sterile plants were obtained from backcross progenies, the sterile and fertile individuals being readily distinguished by the form and color of their anthers. Additional male-sterile plants were also obtained by rooting cuttings from the lower stalks of sterile seedlings. The plants were spaced 4 feet apart in rows spaced the same distance. Seasonal conditions in 1946 were very favorable for tomatoes at Davis as attested by the rapid growth of these plants. At the end of the season the ground was fairly well covered by plant growth and adjacent plants touched each other in about 75 per cent of the cases.

## RESULTS

The numbers of seeds and fruits produced by each sterile and fertile plant were recorded. Parthenocarpic fruits — usually distinguishable by their smaller size and very angular shape — were not counted in these observations. In addition, a count was made of the number of fruits set by a sample of 100 flowers on each of four representative sterile plants in each plot. All seeds produced by the sterile plants were counted; the much higher seed yield of the fertile plants was

TABLE II—ANALYSIS OF VARIANCE OF FRUIT AND SEED PRODUCTION IN TEST OF VARIOUS DESIGNS OF FERTILE AND MALE-STERILE PLANTS

	Means			$\sigma$ Diff.	Variance		
	Treatment 1	Treatment 2	Treatment 3		Rows	Columns	Treatments
<i>Fertile Plants</i>							
Total seeds per plot.....	106,000	131,000	122,000	21,000	$3.92 \times 10^8$	$2.36 \times 10^8$	$4.69 \times 10^8$
Seeds per fruit.....	138	151.8	130.8	13.5	100.8	13.22	34.3
Total fruits per plot.....	794	889	933	313	8,320	14,000	15,200
<i>Sterile Plants</i>							
Total seeds per plot.....	2,686	3,151	7,757	2,025	4,290,000	21,000	23,000,000*
Seeds per fruit.....	25	22.8	35.5	4.34	7.45	23.20	138.40*
Total fruits per plot.....	112	140	217	44.8	5,700	780	8,950
Fruits per 100 flowers.....	1.5	2.7	4.7	†	0.314	0.347	2.167*
*P value is significant at the 0.05 level.							

estimated from the quotient of the total seed weight and the weight of 100 seeds from the same lot.

The tabulations of total seeds and fruits per plot and the mean number of seeds per fruit of both the fertile and sterile groups were subjected to analysis of variance (Table II). Since the number of fruits set per 400 flowers sampled in each plot was low, it would vary according to the Poisson distribution. Bartlett's transformation (1) was therefore applied to these data before analysis.

A similar analysis of fruit and seed yields per plant is also desirable; however, analysis of variance would not be valid because the interplant variance tends to vary significantly from one plot to another without apparent relation to the number of plants per plot or any other factor except possibly the row location of plots. Bartlett's (2) test for homogeneity of variances was therefore applied to variances of plots grouped according to treatments and also according to rows. (Rows refer here to the orientation of plots and not to the individual rows of plants). Comparisons by means of the *t* test were then made between the means of plant yields of those treatments (or rows) whose plot variances were not heterogeneous. The means and permissible tests for significance between them are summarized in Table III.

TABLE III—FRUIT AND SEED PRODUCTION PER PLANT COMPARED BY MEANS OF THE *t* TEST

Comparison of Treatments	Means			<i>t</i> Value for the Difference Between:		
	Treatment 1	Treatment 2	Treatment 3	Treatments 1 and 3	Treatments 2 and 3	Treatments 1 and 2
<i>Fertile Plants</i>						
Seeds per plant...	13,900	16,300	7,700	5.05**	9.19**	1.87
Fruits per plant...	101.2	111.5	58.3	7.09**	10.6**	1.15
<i>Sterile Plants</i>						
Seeds per plant...	335.8	391.9	486.3	2.73**	<i>a</i>	<i>a</i>
Fruits per plant...	14.00	17.27	13.64	<i>a</i>	<i>a</i>	<i>a</i>
Comparison of Rows	Row 1	Row 2	Row 3	Rows 1 and 3	Rows 2 and 3	Rows 1 and 2
<i>Fertile Plants</i>						
Seeds per plant...	10,750	10,500	12,470	1.29	1.36	0.14
Fruits per plant...	75.9	87.3	80.7	0.59	0.72	1.28
<i>Sterile Plants</i>						
Seeds per plant...	523.6	441.3	302.5	<i>a</i>	<i>a</i>	1.45
Fruits per plant...	19.03	14.16	10.72	4.31**	2.99**	2.69**

\*Difference is significant at the 0.05 level.

\*\*Difference is significant at the 0.01 level.

*a* Statistical comparison is not valid because variances of grouped data are heterogeneous.

As indicated in Table II, the total seed production per plot of the male-sterile plants was significantly higher in treatment 3 than in either of the other treatments, the mean seed number being more than twice as high in either comparison. A similar situation is found in the number of seeds per fruit produced by male-sterile plants, and in the



proportion of male-sterile flowers that set fruit. Similar comparisons applied to data for fertile plants do not reveal any significant differences; in fact, the variance ascribed to treatment is a relatively small share of the total variance. This general similarity in yields of the fertile plants proves that no differences in environmental conditions of the plots could account for the significant differences observed in the yields of the sterile plants.

Since twice as many plants of both types were planted in treatment 3 than in treatments 1 or 2 (see Fig. 1), it is necessary to consider the mean yields per plant — the substance of Table III. Again, the value for treatment 3, 486.3 seeds per male-sterile plant, is considerably higher than the 391.9 seeds in treatment 2, and 335.8 in treatment 1. Statistical significance was found in the difference between treatments 1 and 3; this comparison being the only one warranted by the test for homogeneity of variances. The sterile-plant yields exhibit large fluctuations, partly accounted for by row differences. The highly significant differences between all of the combinations of row means of fruit yields per male-sterile plant indicate considerable heterogeneity between rows, a matter that will be considered in the following section. Since row differences exist, it is worthwhile to compare treatment means within rows, and it is significant to note that the mean seed yield for male-sterile plants in treatment 3 was highest in each of the three rows. The same analysis applied to the mean yields of fertile plants reveals the opposite situation, namely, no row heterogeneity and a significantly *lower* mean seed yield in treatment 3 than in either of the other treatments. According to the data in the two tables, this reduction in seed yield reflects an effect of treatment 3 on fruit number, but not on the mean number of seeds per fruit of fertile plants.

The aforementioned great variability in seed yields of the male-sterile plants was evident in all plots. Since fertile plants were growing in these same plots, it is interesting to compare the variability of the fertile and sterile plants within each plot. Since the great difference in seed yield of the two types would not permit a direct comparison of standard deviations, the coefficient of variation was derived for seed yield per plant of the fertile and sterile plants in each plot. The mean coefficient for all sterile plants is 47.1 per cent and for all fertile plants, 29.9 per cent. If the coefficients are compared separately for each plot, the sterile-plant coefficient exceeds the fertile-plant coefficient in eight plots, and the reverse is true in one plot. A binomial expansion reveals that this disproportionate distribution would occur by chance only once in 51 times.

Seed yields of the sterile plants were plotted on a map of the planting to see if high or low levels of cross-pollination were concentrated in any areas. No regularity was observed except possibly a slightly higher level in the perimeter of the planting. Irregularity was also observed in the position of fruits set on the male-sterile plants. Thus, the fruits were not evenly distributed over the plant, but tended to be clustered in one quadrant or even in a single branch, as if the insect vectors preferred flowers in certain positions.

## DISCUSSION

The results obtained in this test of planting designs generally agree with those of the preliminary plantings. The highest seed yields would be expected in sterile plants that invaded fertile plants to the greatest extent, as they did in treatment 3. For similar reasons, the yield of treatment 3 should greatly exceed that of treatments 1 and 2, and the yield of treatment 2 should exceed that of treatment 1, but not by so large an extent. The data expressed in yields per plot bear out these assumptions. The seed yields per plant rank in the expected order, and differ significantly in the only permissible comparison of the three — namely, between treatments 1 and 3. The crowding of plants in treatment 3 resulted in smaller growth of both the fertile and the sterile plants. Corresponding to their smaller growth, the fertile plants of treatment 3 yielded only about half as many fruits and seeds as in other treatments. If, in spite of this decreased plant size, the sterile plants in treatment 3 were still able to exceed the seed yield of those in other treatments, the former must have been subject to a much higher intensity of cross-pollination. This conclusion is verified by two findings: — the mean number of seeds per fruit, and the proportion of flowers that set fruit were significantly higher in the sterile plants of treatment 3 than in those of other treatments.

The preliminary findings might be interpreted to predict a difference of a higher order between treatments 1 and 2; however, the effect of branch direction in this first test was greater in the indeterminate variety than in the determinate one, the latter variety, Pearson, being used again in the test of planting designs.

It was noted that in treatment 3, the paired fertile and sterile plants grew in fair equilibrium; the sterile plant did not tend to overcrowd the fertile member. It is questionable whether indeterminate varieties would behave similarly, because branches of their sterile representatives greatly outgrow those of the fertile plants. At the time of transplanting, the pairing of sterile and fertile plants of similar size in treatment 3 was attempted, but even large differences between members of a pair were unavoidable. If this initial advantage were to give a fertile or sterile plant the opportunity to overcrowd its mate later in the season, a negative correlation between yields of the two types might be expected. The calculated correlation coefficient,  $+0.279$  does not reveal any such tendency; at least if this tendency did exist, it was obscured by the much stronger tendency for both members of a pair to respond similarly to environmental conditions.

Row heterogeneity is unmistakable in the mean fruit yields per male-sterile plant and is also suggested by the mean seed yields (Table III). Also, a relatively high variance attributable to rows was noted for total fruits per plot, but this value was not high enough to indicate a significant heterogeneity (Table II). It is unlikely that this difference between rows is inherent in a difference in soil, amount of irrigation, or other environmental factors because the same analysis applied to fertile plants growing in the same plots does not reveal any such heterogeneity. Instead, the difference should be sought in

the plants themselves. The row heterogeneity of the sterile-plant yields is contributed chiefly by the fact that values of row 3 are much lower than those of rows 1 and 2. The sterile plants of row 3 were noticeably smaller, corresponding to their decreased seed and fruit yields; on the other hand, the percentage of their flowers that set fruit was not lower. One possible explanation of the smaller growth is the fact that the sterile plants in row 3 were propagated by rooting cuttings from male-sterile plants identified in the greenhouse. Cuttings of determinate varieties apparently develop into smaller plants; in fact, if cuttings are taken from distal shoots of mature determinate plants, they often cease growth altogether after developing one or two leaves. A cutting taken from any position in a determinate plant seems to retain the determination of growth peculiar to that position.

Heretofore the high cost of labor required for emasculation and pollination, and, as discussed recently by Larson (5), the inconvenience of hiring large crews for the short period of pollination, constitute serious obstacles to the commercial production of hybrid tomato seed. Now genetically male-sterile plants can be used to circumvent emasculation. Furthermore, the present experiment suggests that cross-pollination by insects might be utilized as a supplement to, or possibly even as a substitute for, hand-pollination in the production of  $F_1$  hybrid seed. Although the yield of hybrid seed set on male-sterile plants by insect pollination is low in comparison with the seed yield of fertile plants, it amounts to 486 seeds per plant or more than 1,000,000 seeds per acre in treatment 3 under conditions of the present tests. Hybrid seed yields in all treatments would surely be welcome supplements to seed crops resulting from hand-pollination. Whether cross-pollination by insects alone would ever be adequate for the production of hybrid tomato seed is uncertain; however, the following points might be considered in relation to this proposal:

1. *Seed or Fruit of the Fertile Parent Could Be Utilized*:—In this respect the production of hybrid tomato seed would possess an advantage not enjoyed by the current methods of producing hybrid corn seed. The inbred parents of hybrid corn are relatively low yielding and rather worthless in themselves, whereas vigorous tomato hybrids have been obtained repeatedly from parents that are important commercial varieties—for example, Pritchard, Rutgers, and Earliana (4, 5).

2. *Insecticides Used to Combat Destructive Insects Might Lower the Production of Hybrid Seed by Killing the Pollen Vectors*:—The arsenates used to control hornworms and various fruit worms are known to be very harmful to honey bees. Two dustings were applied in the present experiment, and for a few days following each application the native solitary bees that are responsible for transferring tomato pollen were observed to be less abundant, actual counts of their frequencies not being attempted. After a period of 3 or 4 days, however, the vectors seemed to resume their usual activity; notwithstanding many bees might have been killed by the insecticide. Similar observations have been made of the frequency of visits of honey bees and native solitary bees to alfalfa flowers following applications of

DDT (6). Although this does not seem to be a serious problem, it would seem advisable to limit applications of insecticides to the very least amount necessary to check destructive worms, and to select insecticides that are least toxic to the pollen vectors.

3. *If Sterile and Fertile Plants Are Paired as in Treatment 3 of the Present Experiment, Some Reliable Method of Distinguishing Fruits of the Two Parents Will Be Needed:*—Differences in fruit shape, the use of such genic markers as *Yy* for difference in skin color, *Jj*, determining the presence or absence of abscission joint in the pedicel, or the *Rr* fruit color difference employed in the present experiment might be used. Only those genes could be used that would not have an undesirable expression in the  $F_1$  hybrids. In regard to point 1, it might be necessary to incorporate the recessive marker in the male-sterile parent.

4. *The Cost of Plant Production Would Need to Be Considered:*—Seeds must be sown earlier than usual in order to have plants flowering for identification of male-sterile individuals at the time of transplanting. Plants that have reached the flowering stage are often leggy, but well adapted to propagation by cuttings. It is possible thereby to increase the number of male-sterile plants by five to seven times. For the reason previously mentioned, this practice might not be satisfactory with determinate varieties.

5. *Higher Yields of Hybrid Seed Can Be Obtained by Adjustment of Other Factors:*—The preliminary tests revealed, in addition to the effect of distance, a marked influence of the variety of the pollen parent upon the amount of cross-pollination. Thus, pollen parents that were more effective and others less effective than Pearson in this respect were found. A difference in seed-yielding capacity of the variety of the male-sterile parent used is also conceivable. Furthermore, great variation in the amount of cross-pollination was observed in different localities, the levels of crossing being both higher and lower than those obtained at Davis. The evidence already available, therefore, suggests that appropriate combinations of seed and pollen parents, localities, and planting designs might further increase the yield of hybrid seed resulting from natural cross-pollination.

#### SUMMARY

In preliminary tests, branches of male-sterile tomato plants that grew toward adjacent fertile plants set more fruits by natural cross-pollination than those that grew toward other male-sterile plants. Subsequently, the amount of natural cross-pollination was tested in different planting arrangements, each of which included equal numbers of fertile and male-sterile plants of the variety Pearson. Here, also, the production of fruits and seeds by male-sterile plants varied according to the distance between fertile and sterile branches. The highest yield per plant of hybrid seed — 486 seeds or about 4 per cent of the mean yield of fertile plants — was obtained when fertile and male-sterile branches intermingled in an arrangement in which the two types of plants were spaced 6 inches apart in pairs, the pairs being

set at the regular planting distance. The smaller growth of the plants resulting from these crowded conditions was offset by a significantly larger number of seeds per fruit, and a significantly larger proportion of flowers that set fruit. The great variability noted in seed yields per male-sterile plant and in other observations reveal certain aspects of the habits of the insect vectors that are responsible for transferring tomato pollen. The bearing of these findings on the production of  $F_1$  hybrid seed is discussed.

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## Effect of Date of Sowing, Spacing and Foliage Trimming of Plants in Flats on Yield of Tomatoes<sup>1</sup>

By ERNEST H. CASSERES, *Cornell University, Ithaca, N. Y.*

THE first two weeks of the tomato season are usually the most remunerative for the market gardener so ways of securing a good first early crop are always sought. With this in mind, some market gardeners in certain areas of New York sow their tomato seed too early; consequently their plants are likely to be overhardened at field setting time. Some growers practice various forms of foliage removal or "trimming". The distance at which plants are grown in the flats prior to field setting varies.

Reports on the effect of trimming tomato plants (without topping them) before setting them out in the field indicate that the practice is of no advantage in promoting earlier maturity. Hardening has been shown by various investigators to be either of no advantage or detrimental to the early yield of tomatoes. Spacing of the plants in the flats prior to field setting, as it affects the early and total yields, appears to have received little or no attention from the experimental point of view.

Most of the experimental evidence available gives information separately on the effect of hardening and of trimming. This study was planned to bring together these two factors with the addition of the factor of spacing in the flats, all combined into one factorial experiment in an effort to obtain information which might be of value to commercial tomato growers, especially market gardeners specializing in the early trade.

This paper reports, therefore, on the influence of three cultural practices followed in the greenhouse as they affect the early and total yield of tomatoes in the field as obtained under New York growing conditions in 1945.

The factors considered are:

1. Date of sowing the seed in flats: February 15, March 15, April 12.
2. Spacing of plants in the flats: 2 by 2 and 4 by 4 inches apart.
3. Removal of various amounts of foliage from the plants while still in the greenhouse. This involved no topping since the longer leaves were brought together above the growing point and clipped off.

The three lots of seed sown 4 weeks apart were of the Earliana variety, Morse 498 strain. The plants were grown in the greenhouse in flats until the field setting date on May 31 under the usual greenhouse cultural methods except for the differential treatments summarized in Table I.

<sup>1</sup>Paper No. 287. Department of Vegetable Crops, Cornell University, Ithaca, New York.

The author is indebted to Dr. H. C. Thompson, Department of Vegetable Crops, Cornell University, under whose direction this work was carried out, for his guidance and constructive suggestions.

TABLE I—SUMMARY OF DIFFERENTIAL TREATMENTS GIVEN IN THE GREENHOUSE BEFORE THE PLANTS WERE SET IN THE FIELD

Date Seed Sown	Date Pricked Out	Spacing in Flats	Number Times Trimmed	Weeks Old at Field Setting	Date Field Set
Feb 15	Mar 5	2 X 2 4 X 4	4	15	May 31
		2 X 2 4 X 4	0	15	May 31
Mar 15	Apr 2	2 X 2 4 X 4	2	11	May 31
		2 X 2 4 X 4	0	11	May 31
Apr 12	May 5	2 X 2 4 X 4	1	7	May 31
		2 X 2 4 X 4	0	7	May 31

The plants grew, up to the time of field setting, for periods of 7, 11 and 15 weeks in flats which allowed either 8 or 32 cubic inches of soil per plant. Half of them received the trimming treatment. Three replications of a 10-plant row of each treatment were made, making a total of 360 plants set in a fertile Chenango gravelly silt loam on a farm near Ithaca, New York.

Fruit harvested from August 1 to August 16 was considered the early yield and the total yield comprised the fruit picked during the entire harvest period of 5 weeks. Sound fruit over 2 ounces in weight was considered marketable. The early yields by weight are given in Table II.

TABLE II—EFFECT OF TIME OF SOWING SEED AND OF SPACING OF PLANTS IN FLATS ON EARLY YIELD OF FRUIT (POUNDS) HARVESTED FROM SIX PLOTS OF TEN PLANTS EACH\*

Date Seed Sown	Spacing in Flats		Total Per Sowing (Pounds)	Average Twelve Plots (Pounds)
	2 Inches X 2 Inches (Pounds)	4 Inches X 4 Inches (Pounds)		
Feb 15	8.65	34.65	43.30	3.60
Mar 15	15.65	59.30	74.95	6.24
Apr 12	16.60	90.05	106.65	8.88

Total weight

40.90

184.00

Aver. weight of 18 plots

2.27

10.22

Least difference for significance at odds of 99:1

Between average yields of 12 plots at each date of sowing.....1.94

Between average yields of 18 plots at each spacing in the flats.....1.59

\*The analysis of variance showed no significant differences between trimmed and untrimmed plants and for this reason the data are condensed to show only the effect of the other two factors.

The analysis of variance for the early yield data given in Table II showed highly significant differences for date of sowing and for spacing of plants in the flats as well as for their interactions. Foliage trimming did not produce any significant differences. When the plants were grown at the wider spacing in the transplanting flats the differ-

ences in early yield due to age were more striking than when the plants were grown closer together. A notable superiority in early yields was shown by plants grown from seed sown April 12 spaced at 4 by 4 inches in the flats. Such plants yielded 5.4 times more early fruit than plants of the same age grown at 2 by 2 inches until field setting time.

The marketable fruit harvested during the entire harvest season of 5 weeks is shown in Table III. As in the case for the early yields, trimming did not produce any significant differences in the total yields, hence the data are again condensed.

TABLE III—EFFECT OF TIME OF SOWING SEED AND OF SPACING OF PLANTS IN FLATS ON THE TOTAL YIELD OF FRUIT (POUNDS) HARVESTED FROM SIX PLOTS OF TEN PLANTS EACH

Date Seed Sown	Spacing in Flats		Weight	
	2 Inches X 2 Inches (Pounds)	4 Inches X 4 Inches (Pounds)	Total Per Sowing (Pounds)	Average Twelve Plots (Pounds)
Feb 15	365.50	541.10	906.60	75.57
Mar 15	437.05	796.80	1233.85	102.82
Apr 12	575.90	858.40	1434.30	119.52
Total weight	1378.45	2196.30		
Aver. weight of 18 plots	229.73	366.11		

Least difference for significance at odds of 99:1

Between average yields of 12 plots at each date of sowing.....13.72

Between average yields of 18 plots at each spacing in the flats.....11.16

Larger total yields were obtained by sowing the seed later and growing the plants at the wider spacing in the transplanting flats, as shown by the data in Table III. The analysis of variance showed that the odds were higher than 99:1 in favor of the later dates and the wider spacing in the flats. The interaction of both factors was significant at odds of 19:1. Trimming the foliage had no significant effect, with one exception. Only when a separate analysis was made for the yields from plants started in February did the untrimmed controls give significantly higher yields at odds of 19:1 over plants of the same group which were trimmed four times.

The first fruit to ripen on normal tomato plants are those borne on the first and second clusters and the number that ripen influence the size of the early yield. Records kept during blossoming and maturation showed that plants grown from seed sown in April and set in the field when 7 weeks old produced a great many more fruit on the first two clusters than plants from sowings of the previous two months, with highly significant differences. Trimming had no significant effect.

At the end of the harvesting period after all the marketable ripe fruit and culls had been picked off the vines, the remaining green fruit was counted and weighed. The resulting data indicated that while the plants of the three ages set approximately the same number of fruit, the youngest plants ripened a greater portion of their fruit during the 5-week harvest period and the older plants still had much green fruit left on them when picking ceased.



## SUMMARY AND DISCUSSION

Early and total yields of tomatoes from plants started in flats in the greenhouse on February 15, March 15 and April 12 and planted outdoors at the same time were highly significant with differences favoring the later plantings. All plants were grown in the greenhouse until May 31 when they were set out in the field.

The plants were grown in the transplanting flats at 4 by 4 and at 2 by 2 inches apart which allowed 32 and 8 cubic inches of soil per plant respectively. The wider spacing gave significantly higher early and total yields over the entire experiment. The advantage of the wider spacing was especially noticeable in the early yield of the plants from April sown seed. In that group, plants grown at 4 by 4 inches apart in the flats for 7 weeks produced in the field more than five times the amount of early fruit produced by plants started at 2 by 2 inches in the flats. The difference may be explained by the fact that the many fine new roots in the youngest plants grown at 4 by 4 inches apart were probably only very slightly disturbed at field setting time allowing rapid continuation of vegetative growth, whereas there was both an increase in the damage caused to the roots at field setting time and a general set-back apparent at that time as the plants were grown closer together and for longer periods in the flats.

There appeared to be a definite relation between the condition of the plants when they were set in the field and the early and total yields produced. Young plants that were tender and capable of quick growth resumption after field setting were factors associated with large yields. This is in agreement with the results of Babb's (1) study on the rate of root growth made by tomato seedlings after transplanting which showed that subsequent rate of growth rather than large initial size was most closely associated with earliness of maturity. The treatments of the experiment herein reported which resulted in hardening reduced the early yields in proportion to the degree of hardening. This is in accordance with previous reports on the effect of hardening (2, 3, 4, 6, 9, 10, 11).

Foliage trimming was practiced on half of the plants in the flats according to a custom followed by some growers. The treatment, which consisted in removing parts of the longer leaves without topping the plants, was especially detrimental to the appearance and condition of the older plants but did not reduce or increase the early or total yields significantly. Exception is made of the plants started in February which were trimmed four times and which did show a significant total yield reduction in a comparison with untrimmed plants of the same age. These results confirm many reports on pruning (5, 7, 8, 12, 13, 14), which show that under various conditions removal of vegetative tissues does not favor an increase in the early yields and has little or no effect on the total yields.

Results obtained in the experiment favored at odds of more than 99:1 the sowing of tomato seed 7 weeks prior to field setting rather than 11 or more weeks in advance. This suggests the desirability of further study over a period of several seasons to determine the effect

of sowing seed at intervals between 6 and 11 weeks before the field setting date. The experiment also showed an advantage in earliness derived from wider spacing of the plants in the flats before field setting. This indicates the need of determining the influence of spacings between 2 and 4 inches, and also suggests that under certain conditions the use of deeper flats than those used in this work may prove beneficial by allowing more soil per plant without increasing the greenhouse area required.

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# Studies Related to Field Plot Technique With Tomatoes<sup>1</sup>

By T. M. CURRENCE, *University of Minnesota, St. Paul, Minn.*

INFORMATION on the efficiency of different size and shape of plots for field experiments with tomatoes and the amount of competition between plants grown at different spacings should be useful in making variety trials and other types of experimental plantings. Conditions related to the problem are variable in different locations and the worker can best adjust the size and shape of plots to meet his particular conditions or type of experiment if he is aware of their comparative efficiency.

For this study a block of 864 John Baer tomato plants were grown and records were taken on yields and earliness. Plant spacing was 6 feet between rows and 3 feet in the rows so that the area was 144 by 108 or 15,552 square feet in size. In analyzing the data, it was assumed that six treatments or varieties were being tested in a randomized block arrangement. There were no missing plants, but 16 were badly diseased or injured otherwise, and obviously did not produce normally. In these instances a calculated yield was used which was the average of the four adjacent plants. The plots were assumed to be 1, 2, 3, 4, 6, 9, 12, 18 and 36 plants in length and 1, 2, and 4 plants in width, each length being combined with each of the widths. Thus the maximum plot was 108 by 24 feet in size, being four rows wide and 36 plants long. The minimum size was a single plant, the plot being 3 by 6 feet. Total degrees of freedom were 863 for the single plant arrangement with six treatments per block. There were 144 hypothetical blocks or 143 degrees freedom for blocks and 720 for error. For the maximum plot size, 36 plants long and 4 rows wide there were 144 plants per plot and only one hypothetical block for the six treatments with five degrees of freedom all of which went into error. Tables I, II and III are presented as illustrations of the calculations made in finding the different standard errors. Table I shows calculations for the entire

TABLE I—ANALYSIS OF VARIANCE OF EARLY YIELD ON INDIVIDUAL TOMATO PLANTS

Variation	Degrees Freedom	Sum of Squares	Mean Square	Standard Error	S.E. in Per Cent of Mean
Between blocks.....	143	297.969	2.084	—	—
Within blocks.....	720	859.095	1.194	1.093	67.08
Total.....	863	1157.064	—	—	—

population when individual plants were considered as entire plots. Such plots are characterized by high variability in relation to their mean yields. Table II gives the calculations on data that were obtained by adding two plants consecutively in the rows. Table III also represents plots that were two plants in length but in this case four adjacent

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TABLE II—ANALYSIS OF VARIANCE ON EARLY YIELDS OF TOMATO PLOTS COMPOSED OF TWO CONSECUTIVE PLANTS IN THE ROW

Variation	Degrees Freedom	Sum of Squares	Mean Square	Standard Error	S.E. in Per Cent of Mean
Between blocks.....	71	481.757	6.785	—	—
Within blocks.....	360	1038.180	2.884	1.698	52.07
Total.....	431	1519.937	—	—	—

TABLE III—ANALYSIS OF VARIANCE ON EARLY YIELDS OF TOMATO PLOTS COMPOSED OF TWO CONSECUTIVE PLANTS IN THE ROWS AND FOUR ADJACENT ROWS

Variation	Degrees Freedom	Sum of Squares	Mean Square	Standard Error	S.E. in Per Cent of Mean
Between blocks.....	17	157.326	9.254	—	—
Within blocks.....	90	2353.232	26.147	5.113	39.20
Total.....	107	2510.558	—	—	—

rows were combined to make up plots that were two plants in one direction and four plants or rows in width. In this way, additional combinations of length and width of plots were made up.

Harvesting began July 24 and ended September 20. Fifteen pickings were made over this period with intervals of 3 to 6 days between pickings. Ripe fruits of individual plants were harvested and weighed in grams and converted to pounds after all pickings were added. The analysis of variance calculations were on pound yields and were made on the first seven pickings as representing the early yields and on the entire season to represent total yield. Standard errors in percentage of the means are shown in Table IV. They are based on the variance

TABLE IV—STANDARD ERRORS, EARLY AND TOTAL YIELDS IN PERCENTAGE OF MEAN OF DIFFERENT SIZE AND SHAPE PLOTS OF TOMATOES

Width of Plots		Length of Plots in Number of Plants and Feet								
Feet	Rows	1(3)	2(6)	3(9)	4(12)	6(18)	9(27)	12(36)	18(54)	36(108)
<i>Early Yield</i>										
6	1	67.03	52.07	43.82	41.03	36.15	27.76	25.68	21.88	14.90
12	2	51.41	41.60	35.42	33.95	29.68	26.22	24.79	23.31	19.40
24	4	45.06	39.20	35.72	36.05	33.28	31.91	31.17	22.40	28.14
<i>Total Yield</i>										
6	1	25.32	17.23	14.52	12.34	10.44	9.01	8.03	7.07	5.55
12	2	24.30	13.14	11.53	10.36	9.27	7.89	7.31	7.08	5.69
24	4	12.43	9.52	8.30	9.29	7.43	6.36	6.34	6.37	4.60

within blocks and are thought to furnish a usable method for comparing the relative efficiency of different plots. The larger plots produced smaller errors and for early yields a long, narrow plot was more efficient than the same area in a short wide plot. As an illustration of this, it may be seen that the plots of three plants in length and four plants wide contain the same number of plants and the same area as that of the single row plots 12 plants long. The gain due to plot shape is the difference between an early yield error of 25.68 and one of 35.72

per cent. For total yield this gain due to a long, narrow plot was not apparent; the respective figures for the above plots being 8.03 and 8.30. However there does seem to be a small but rather consistent reduction when long plots are compared with wider ones having the same number of plants. Table V was made up from Table IV in order to compare different plots for efficiency in the use of space. The for-

mula used for the figures is  $N = \frac{(S.E.)^2}{(3.5)}$ . The difference of 10 per

cent was chosen arbitrarily as one which would probably represent some financial significance to the grower and would amount to 1000 pounds if the yield were 5 tons per acre. It is well known that large plots reduce the standard error and therefore the required number of replicates to demonstrate the significance of a given difference. Under conditions that limit available space for a test it is generally recognized that small plot size with numerous replicates will provide greater efficiency in measuring a given percentage difference. Table V illustrates

TABLE V.—NUMBER OF DIFFERENT SIZE AND SHAPE OF TOMATO PLOTS REQUIRED TO GIVE AN EFFICIENCY ADEQUATE FOR DEMONSTRATING STATISTICAL SIGNIFICANCE OF A TEN PER CENT DIFFERENCE BETWEEN MEANS

Width of Plots		Length of Plots in Number of Plants and Feet								
Feet	Rows	1(3)	2(6)	3(9)	4(12)	6(18)	9(27)	12(36)	18(54)	36(108)
<i>Early Yield</i>										
6	1	365	222	156	137	106	62	53	38	18
12	2	216	141	102	94	72	56	50	45	30
24	4	166	125	104	106	90	83	79	41	64
<i>Total Yield</i>										
6	1	52	24	17	12	9	7	5	4	3
12	2	48	14	10	9	7	5	4	4	3
24	4	12	7	6	7	4	3	3	3	2

this and shows that the greatest number of replicates is needed for the minimum plot size of single plants but when the area required to measure a 10 per cent difference is calculated, it is noted that the smallest plots require the minimum of total area. For total yield the area required per treatment for single plant plots would be 936 square feet and that for the largest plots would be 5184 square feet. The basis for this is, of course, the fact that significance of a difference depends on the standard errors of the two means the size of which are largely dependent on the number of observations upon which the means are based. In small areas such as greenhouse tests it is usually preferable to utilize the smallest practical plot size in order to secure the largest practical number of replicates. Considering that tomatoes are commonly grown as a highly intensive greenhouse crop as well as under different forms of culture outdoors and tests will be made under such conditions it seems apparent that a given plot size and shape would not prove feasible for all tests. Certain tests under field conditions might justify the use of extremely large plots where land and labor

are sufficient to maintain such a planting. It also is apparent that reducing the number of replicates facilitates the keeping of records, and the calculations required in summarizing results. Yield records on tomatoes are multiplied by the necessity of harvesting the crop several times which gives emphasis to the desirability of restricting calculations and tabulating without reducing the general efficiency of a test. On the other hand, it is possible to visualize a condition of adequate clerical and technical assistance but limited field space, field labor or field equipment. Carrying out of earliness or yield tests under such conditions would indicate the use of small plots with numerous replicates.

It is seen from the data on early yield in Table V that it is more expensive to compare strains or treatments for yield of early fruits than it is to compare them with the same degree of accuracy for total yields. The minimum number of replicates required to test a 10 per cent difference is 18 for the single row, 36 plants long. The square feet area needed for a single treatment is 11,664. If 10 treatments are to be compared, the land needed would be more than two and one-half acres. Or if the minimum plot size (single plant) is used in order to save space, the large number of replicates required becomes prohibitive amounting to 3,650 plots for 10 treatments. It would be very laborious to handle the details involved in such a test. Fortunately the recording of dates at which plants ripen fruit and getting average dates when a number of plants are involved is a fairly satisfactory measure of earliness. If statistical comparisons were desired from plots containing 12 plants each the records would show the elapsed number of days from any desired base up to the date when 12 ripened fruits were produced on the plot. Such data for dates of ripening were obtained on the individual plants of this planting. Individual plant observations were averaged when larger plots are used. For single plants the date of ripening standard error was 36.89 per cent of the mean and for early yield it was 67.03 per cent of the mean. Variation was reduced almost half and suggests that if earliness is the major factor to be tested ripening dates may be preferable to early yields. Table VI represents the

TABLE VI—STANDARD ERRORS IN PERCENTAGE OF THE MEANS FOR AVERAGE DATE OF RIPENING OF DIFFERENT SIZE AND SHAPE PLOTS OF TOMATOES

Width of Plots		Length of Plots in Plants and Feet								
Feet	Rows	1(3)	2(6)	3(9)	4(12)	6(18)	9(27)	12(36)	18(54)	36(108)
6	1	36.9	28.3	20.8	20.8	18.8	13.6	14.5	11.7	7.3
12	2	25.6	20.6	19.8	16.3	14.1	12.5	12.5	11.7	9.6
24	4	19.4	16.6	14.3	13.6	13.0	11.7	11.6	11.3	10.4

standard errors in days when this was done on the planting in the same manner that yields were used for Table I. Obviously the use of early yields is not to be entirely condemned when their use can be combined with comparisons on total yield because the pickings and recordings must be made anyway. The tomato grower will usually prefer data on the amount of crop produced in the early part of the season

rather than that on the time required for production to start. Therefore, it may at times be desirable to use ripening dates in combination with early yields when it is not practical to depend entirely on one or the other types of data.

That ripening dates and early yields are directly associated may be taken for granted, but in order to demonstrate the degree of associations for the various plot sizes and shapes correlation coefficients have been calculated by covariance and are presented in Table VII. In

TABLE VII—CORRELATION COEFFICIENTS BETWEEN EARLY YIELD AND AVERAGE DATE TO RIPENING OF DIFFERENT SIZE AND SHAPE PLOTS OF TOMATOES

Width of Plots		Length of Plots in Plants and Feet								
Feet	Rows	1(3)	2(6)	3(9)	4(12)	6(18)	9(27)	12(36)	18(54)	36(108)
6	1	-0.472	-0.578	-0.636	-0.587	-0.534	-0.633	-0.561	-0.662	-0.588
12	2	-0.569	-0.606	-0.670	-0.631	-0.692	-0.709	-0.653	-0.740	-0.859
24	4	-0.480	-0.708	-0.799	-0.882	-0.807	-0.847	-0.826	-0.861	-0.868

all cases there is a statistically significant negative value for  $r$  indicating that under the conditions of this test the plots which first came into production also produced the greater yields for the first seven pickings. In general the  $r$  values are lower for the smaller size of plots.

### COMPETITION BETWEEN PLANTS

In the event that single plant plots are to be used, the question may arise as to competition between plants. It is apparent that a small plant growing beside a large one will be at a disadvantage if there is competition. There are records available on this which suggest the possibility of spacing plants far enough apart to largely eliminate the possibility of competition. The data on this are yields per plant from different spacings, varying from 1 by 4 to 4 by 4 for three varieties of quite different plant types and three types of training. The yields per plant are summarized in Table VIII.

It is evident that Dwarf Champion and Pritchard did not show significant competition between plants at the 4 by 4 spacing even when grown without staking or pruning, the yields per plant being non-significantly greater at the 3 by 4 than at the 4 by 4 for both varieties for the untreated. Break O'Day is a variety that grew to a relatively large plant under the conditions of these studies and produced a lower yield per plant at the 3 by 4 than at the 4 by 4 spacing. Evidently when grown without staking, this variety needed at least 4 by 4 spacing to reduce competition between plants to a minimum while the other two varieties were spaced 3 by 4 without significant inter-plant competition.

When grown on stakes without vine pruning the yield per plant was not reduced for any of the varieties until the spacing was reduced to 2 by 4 feet where it became definitely smaller in all cases. When pruned and staked the Break O'Day and Pritchard types seem to definitely show competition at 2 by 4 feet but the Dwarf Champion yield per plant was not markedly reduced even by the 1.5 by 4 feet spacing.

TABLE VIII—POUNDS PER PLANT YIELD OF MARKETABLE TOMATOES FOR FIVE SPACINGS OF THREE VARIETIES AND THREE TYPES OF TRAINING

Spacing (Feet)	Dwarf Champion	Break O'Day	Pritchard
<i>Untreated</i>			
1.0 × 4	2.66	4.10	3.96
1.5 × 4	3.34	5.66	5.23
2.0 × 4	4.31	7.40	7.16
3.0 × 4	5.50	10.18	11.99
4.0 × 4	5.15	11.71	10.82
<i>Staked, Not Pruned</i>			
1.0 × 4	2.58	3.56	4.37
1.5 × 4	3.65	5.92	5.36
2.0 × 4	4.46	6.60	6.95
3.0 × 4	5.87	9.79	10.11
4.0 × 4	5.89	9.22	8.60
<i>Staked and Pruned to Three Stems</i>			
1.0 × 4	2.10	3.92	3.35
1.5 × 4	2.60	4.76	3.71
2.0 × 4	2.95	5.24	5.47
3.0 × 4	3.00	6.13	6.29
4.0 × 4	2.65	6.16	6.02

Based on these results it appears that spacing of about 4 by 5 of large unstaked plants of these varieties under these conditions might eliminate interplant competition and 4 by 4 for smaller growing types or 3 by 4 when staking is to be practiced. Competition between plants may also be a factor for consideration with plots containing more than a single plant. Since the maximum yield per area is usually desired by tomato producers the plants are generally grown with fairly close spacing, thereby causing competition. It would seem that experimental tests should approximate these conditions as nearly as possible. This presents some difficulties, especially for a variety test which would include a wide range in size of plants. A variety of small plant size such as Pearl Harbor would not require the same spacing as a larger plant type such as Rutgers. To vary the spacing within a test does not seem generally practical unless three row plots might be grown and records taken only from the center row. This size of plot would be large and wasteful of space under most conditions. Also, there is the problem of missing or abnormal plants. If the spacing is wide enough to eliminate competition, a calculated figure might justifiably be used for a missing plant, but if there is competition between plants of the variety, the worker is at a loss to know the degree of competition for the particular variety and, therefore, cannot arrive at a satisfactory method of calculating missing plant results. It, therefore, seems that good reasons often exist for wide spacing of plants to eliminate competition between them.

#### SUMMARY

Studies on the efficiency of different sizes and shapes of tomato plots are reported, also a study comparing individual plant yields for three varieties grown at five different spacings and with three types of training.



For date of ripening, early yield, and total yield, the standard errors in percentage of the mean decreased as size of plots increased.

For early yield, single-row plots were more efficient than two- or four-row plots of equal size. For total yield and date of ripening, single-row standard errors were not appreciably less than those of two- and four-row plots.

Date of ripening gave lower standard errors in percentage of the mean than comparable plots gave for early yields. Significant negative correlation coefficients were obtained between early yields and dates of ripening for all plot sizes and shapes. Larger plots tended to show a closer relationship than the smaller ones.

Yields of untreated single plants at different spacings suggest that there was no competition between plants at 3 by 4 feet for the varieties Dwarf Champion and Pritchard. For Break O'Day the yield at 3 by 4 feet was less than at 4 by 4 feet suggesting that competition occurred at 3 by 4 feet.

Plants grown on stakes, but not pruned, showed definite reduction in yields at 2 by 4 feet as compared with 3 by 4 and 4 by 4 feet for the three varieties.

When staked and pruned to three stems the Dwarf Champion variety gave indications of competition only at the closest spacing which was 1 by 4 feet. Pritchard and Break O'Day varieties under this treatment showed yield reduction at 2 by 4 feet.

## Permanent Standards for Chemical Test for Pungency in Peppers

By L. O. VAN BLARICOM and J. A. MARTIN, *South Carolina  
Experiment Station, Clemson, S. C.*

THE procedures of Fodor (1) and Tice (2) for testing the pungency or capsaicin content of peppers have been modified by Ting and Barrons (3). This modified procedure employs color standards using Naphthol Yellow and Malachite Green. The authors found these standards to have two serious faults. First, various lots of the dyes varied so much that it was impossible to reproduce a set of colors from different lots of dye. Second, the solutions were not stable and would change color in a few hours. This necessitated making up standards frequently, and, unless the same lots of dye were used each time, reproducible standards could not be obtained.

After a number of preliminary trials, potassium dichromate and copper nitrate were found to produce satisfactory colors. A set of standards prepared with these chemicals was reproduced and matched perfectly after two years.

The potassium dichromate can be obtained in a stable pure form. The copper nitrate is unstable and deliquescent. However, the form  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ , meeting American Chemist Society standards and dried under vacuum for 24 hours at 30 degrees C was found to be satisfactory, and reproducible colors could be prepared. If the copper nitrate solution is cloudy, 1 or 2 drops of nitric acid will clear the solution.

### DIRECTIONS FOR MAKING MODIFIED COLOR STANDARDS

Make up color standard by adding solution 1 to solution 2 in the proportions shown.

Solution 1. Dissolve 50 grams  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$  in 50 cc water.

Solution 2. Dissolve 1 gram  $\text{K}_2\text{Cr}_2\text{O}_7$  in 100 cc water.

Color Standard Number	Solution 1 (cc)	Solution 2 (cc)	Comparative Degree of Pungency
1	.5	15.5	Sweet
2	.75	15.25	Slightly mild
3	1	15	Mild
4	1.5	14.5	Slightly hot
5	2	14	Hot
6	3	13	Hot
7	4	12	Very hot
8	6	10	Very hot
9	10	6	Extremely hot
10—Special—dissolve 10 grams $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ in 10 cc of solution 1.			

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# Some Problems in Sampling the Sweetpotato Plant<sup>1</sup>

By O. A. LEONARD and W. S. ANDERSON, *Mississippi Agricultural Experiment Station, State College, Miss.*

IN connection with recent studies by the authors on the nutrition of the sweetpotato plant, it was necessary that many samples be taken from field plots and sand cultures for analyses of mineral and other constituents of the crop. Since very little work had previously been done involving mineral analysis of the sweetpotato, there appeared to be no standard procedure for satisfactorily sampling this plant. In the first experiment, mature leaf-blades and the entire vine were analyzed. The second year it was decided to study in some detail the relationship between the composition of various parts of the sweetpotato plant. From the determinations at hand it was believed a valid estimate could be made of the relationship between the mineral content of the leaf-blades and the other parts of the plant. This paper presents the results of a simple statistical study of these data.

Correlation coefficients were calculated and are presented diagrammatically in Figs. 1 to 6. Highly significant correlations were

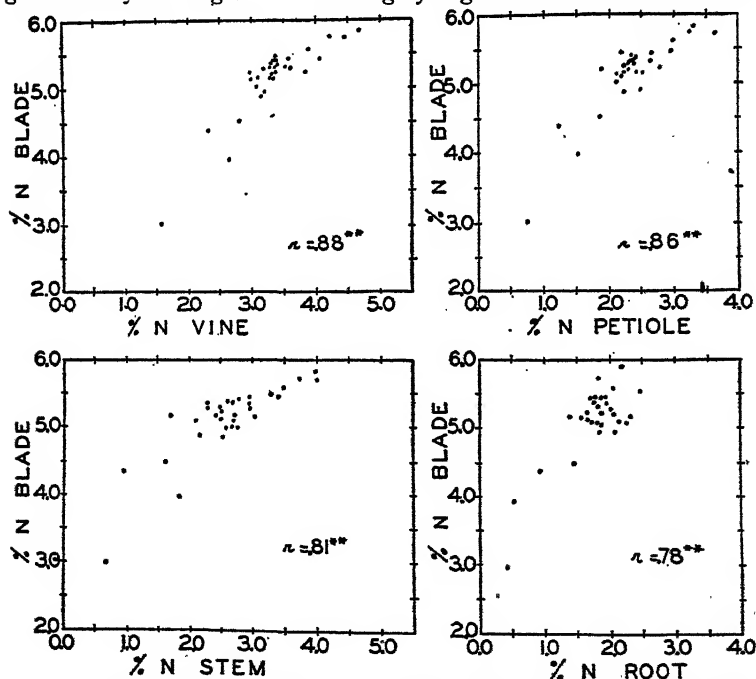


FIG. 1. Correlation between the total nitrogen content of the leaf-blades and that of the petioles, stems, storage roots and vines.

<sup>1</sup>Published with the approval of the Director, Mississippi Experiment Station, paper No. 139, new series.

The authors wish to thank Mr. Marvin Gieger for the chemical determinations, and International Minerals and Chemical Corporation for help given by them in conducting this study.

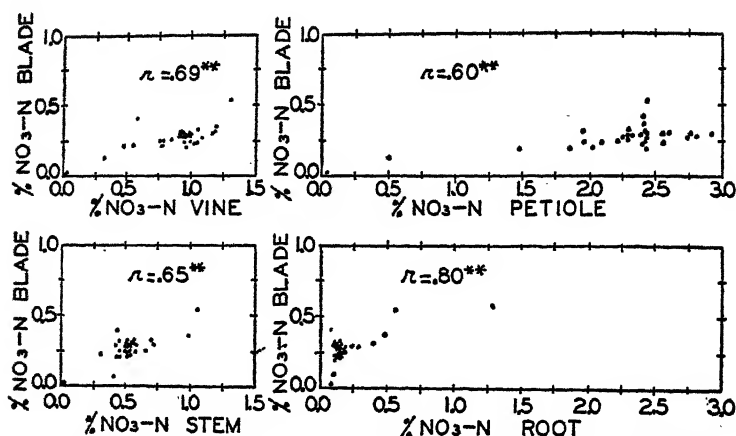


FIG. 2. Correlation between the nitrate nitrogen content of the leaf-blades and that of the petioles, stems, storage roots and vines.

found between the mineral composition of the leaf-blades and between other parts of the vines. In general, a higher correlation existed between contents of blade and petiole than between contents of blade and stem. The correlation between the mineral content of blades and storage roots was relatively high for total nitrogen, nitrate nitrogen, phosphorus and potassium. Little, if any, correlation existed between the percentages of calcium or magnesium in blades and storage roots.

The results of this study indicate that it is not necessary to sample

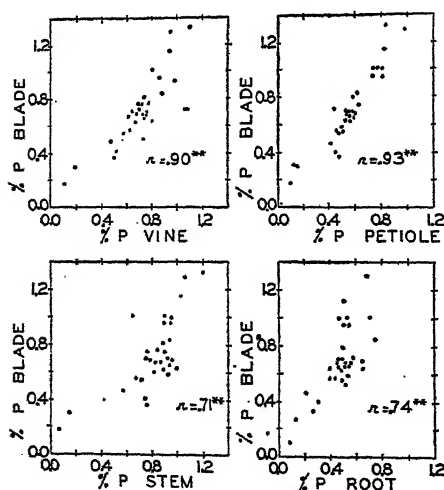


FIG. 3. Correlation between the phosphorus of the leaf-blades and that of the petioles, stems, storage roots and vines.

different parts of the plant in order to arrive at a valid estimation of the composition of its various parts. With the exception of calcium and magnesium in the storage roots, fairly satisfactory correlations were found to exist between various parts of the sweetpotato plant. In estimating the composition of the whole vine from leaf-blade analyses, some caution should be exercised. If leaf-shedding has been severe, the proportion of leaf to stem may be changed considerably, thus affecting the composition of the whole vine.

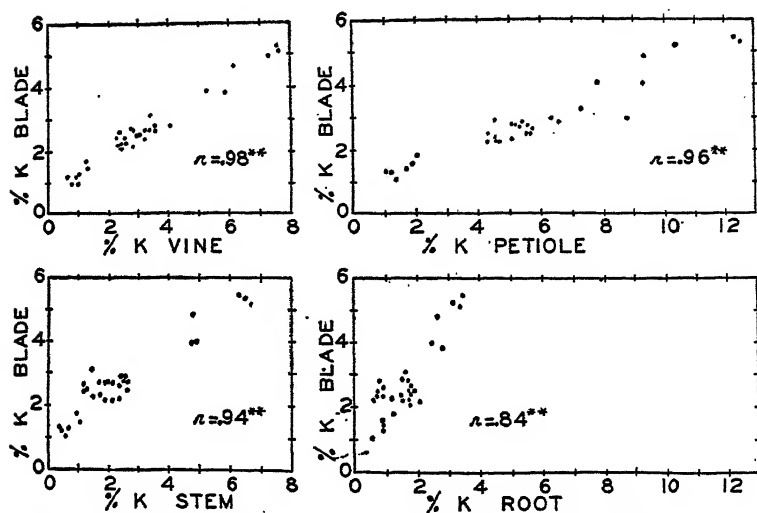


FIG. 4. Correlation between the potassium of the leaf-blades and that of the petioles, stems, storage roots and vines.

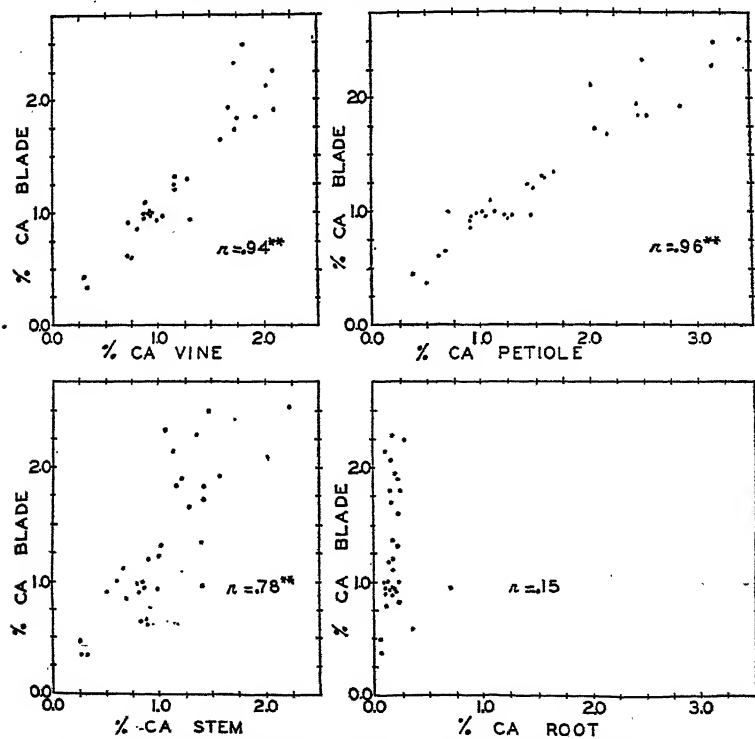


FIG. 5. Correlation between the calcium of the leaf-blades and that of the petioles, stems, storage roots and vines.

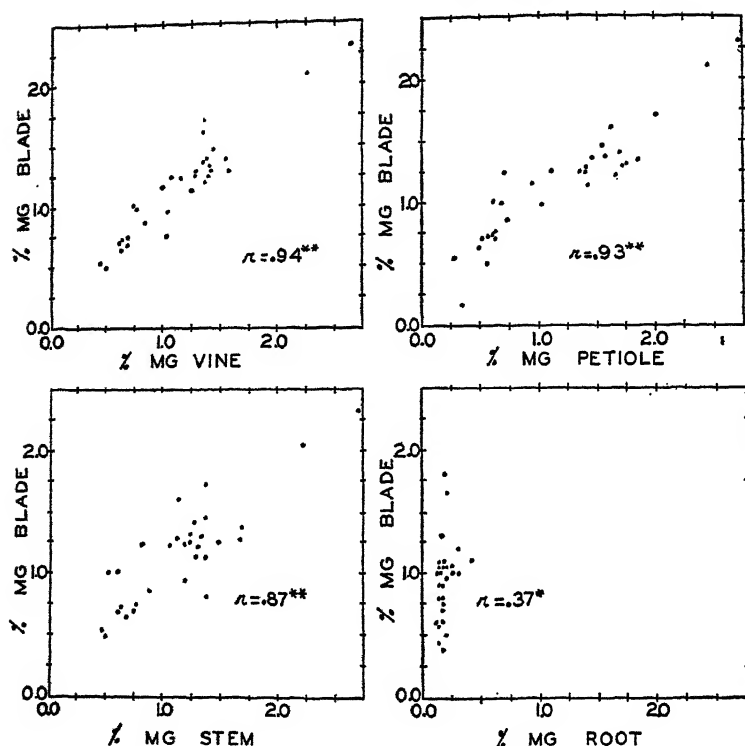


FIG. 6. Correlation between the magnesium of the leaf-blades and that of the petioles, stems, storage roots and vines.

Because of the information gained in the above study, leaf-blades only were used as samples in the nutrition studies in 1946. The leaf-blades collected were the first five fully enlarged ones counted from the tips of individual vines. On each plot 10 vines were sampled on each sampling date; thus 50 blades were collected from each plot. Blades were collected five times during the season at approximately 24-day intervals. The results obtained from these studies indicate that this method of sampling is satisfactory for the sweetpotato plant.

Leaf-blade sampling as described above is quite simple and gives blades from a definite part of the plant. Petioles are about as satisfactory from a chemical standpoint as leaf-blades, but larger samples are necessary and they are more difficult to collect and to dry. In sampling by the leaf-blade method one can compare, with confidence, the nutrient status of sweetpotato plants on different soils at different seasons, as well as from year to year.

# Seasonal Development of Fibrous and Storage Roots of Sweetpotatoes<sup>1</sup>

By O. A. LEONARD and W. S. ANDERSON, *Mississippi Agricultural Experiment Station, State College, Miss.*

THIS study was undertaken because there was no previous information available on the seasonal development of the sweetpotato root system under Mississippi soil and climatic conditions. The only work the authors could find reported on the seasonal development of the root system of the sweetpotato was conducted in Nebraska by Weaver and Bruner (1). They found that root development in the subsoil was abundant, indicating a fairly fertile subsoil. Southern soils are, in general, more highly leached and lower in fertility than Nebraska soils. The differences in soil fertility between the two regions are related to differences in rainfall and temperature. There was reason to expect that the root systems might vary in the same manner that the soils varied.

The nature and fertility of the soil influence the abundance of roots that develop at different depths. A plant having roots deep in the ground should be able to withstand dry weather longer without ill effects than a plant having a root system that is predominately shallow. The study reported herein describes the root development of two varieties of sweetpotato as grown in two distinctly different soils in Mississippi.

## DESCRIPTION OF THE SOILS

The soil types studied were Ocklocknee sandy loam and Ruston sandy loam. The general characteristics of these soils are shown in Table I. The data on mechanical analysis show that the clay content of the Ocklocknee was much higher than that of the Ruston, with the

TABLE I.—MECHANICAL ANALYSES, EXCHANGEABLE BASES, AND PH AT DIFFERENT DEPTHS FOR OCKLOCKNEE AND RUSTON SANDY LOAM

Soil Type and Depth	Mechanical Analyses			Exchangeable Bases			Available P (Bray's Procedure)	pH
	Sand (Per Cent)	Silt (Per Cent)	Clay (Per Cent)	K Me	Ca Me	Mg Me		
Ocklocknee								
Top soil	46.6	41.5	12.8	0.33	5.21	1.20	Medium	5.9
2 ft	23.5	43.7	33.1	0.25	19.19	0.72	Low	5.9
4 ft	20.7	44.7	34.6	0.25	18.79	0.77	Low	6.0
6 ft	22.7	45.3	32.0	0.28	17.66	0.82	Low	6.0
Ruston								
Top soil	69.9	20.2	9.9	0.30	1.68	0.79	Low	5.9
2 ft	61.4	21.2	17.6	0.19	0.66	0.76	Trace	5.1
4 ft	67.0	16.4	16.6	0.12	0.33	0.60	Trace	5.0
6 ft	77.8	11.7	10.5	0.06	0.15	0.50	Trace	5.7

<sup>1</sup>Published with the approval of the Director, Mississippi Agricultural Experiment Station, State College, Mississippi, Journal Paper No. 143.

The authors wish to express their thanks to the International Minerals and Chemical Corporation for aid in conducting these studies.



difference especially marked in the subsoil. The greater clay content of the Ocklocknee signifies that it should have a greater base exchange capacity and a greater water holding capacity than the Ruston. The outstanding difference between the two soils in bases is that the exchangeable calcium was very much lower in the Ruston. An unfavorable calcium-magnesium balance for root development is indicated by the analysis of the Ruston subsoil.

The exchangeable potassium was higher in the Ocklocknee than in the Ruston. Quick test analysis by Bray's procedure that both top soil and subsoil of Ocklocknee was higher in available phosphorus than those of the Ruston. In fact, only a trace of available phosphorus was present in the Ruston subsoil. In addition, nitrogen was undoubtedly more limiting in the Ruston subsoil than in the Ocklocknee subsoil.

#### ROOT DEVELOPMENT IN OCKLOCKNEE SANDY LOAM

The Triumph variety and the Unit I strain of the Porto Rico variety of sweetpotato were grown in alternate rows on Ocklocknee sandy loam at State College, Mississippi in 1944. A 6-8-4 factory mixed fertilizer was applied within each side of the bed in bands at the rate of 600 pounds per acre as the land was prepared. The sprouts were transplanted immediately by hand on May 9, in bedded rows, 1 foot apart, spaced 42 inches apart.

Rectangular pits were dug between the rows in order to examine the root systems; thus, a single pit served for studying the root systems of both varieties. The depth of the fibrous roots was determined by digging below the deepest roots and then cutting upward until roots were encountered. The soil was washed from fibrous and storage roots by spraying the banks of the pit with water, using a 2½-gallon compressed air sprayer. This proved to be a very satisfactory method of exposing the roots. The appearance of the root systems at different times of the year for both varieties is illustrated by Fig. 1, and Fig. 2 shows graphically the seasonal changes in the depths of the fibrous roots as well as the fresh weights of both vines and storage roots.

On June 13, 35 days after transplanting, when the first examination was made, the vines were growing vigorously. The roots had obtained a depth of 40 inches, but were most abundant in the top 12 inches as seen in Fig. 1. Several Triumph roots were observed to begin thickening at this time.

The root systems had reached the water table, a depth of 84 inches, by July 7, 59 days after transplanting. Some Triumph roots were 1 inch in diameter while those of the Porto Rico were smaller.

On August 8, 92 days after transplanting, the roots were 90 inches deep, or about 2 inches deeper than the water table. (The water table had lowered since July 7). Very few roots were found below a depth of 40 inches. Vine growth was good on this date, but by September 8, 122 days after transplanting, it had been checked by dry weather, and some loss of leaves was taking place.

The roots were examined for the last time in 1944 on October 2,

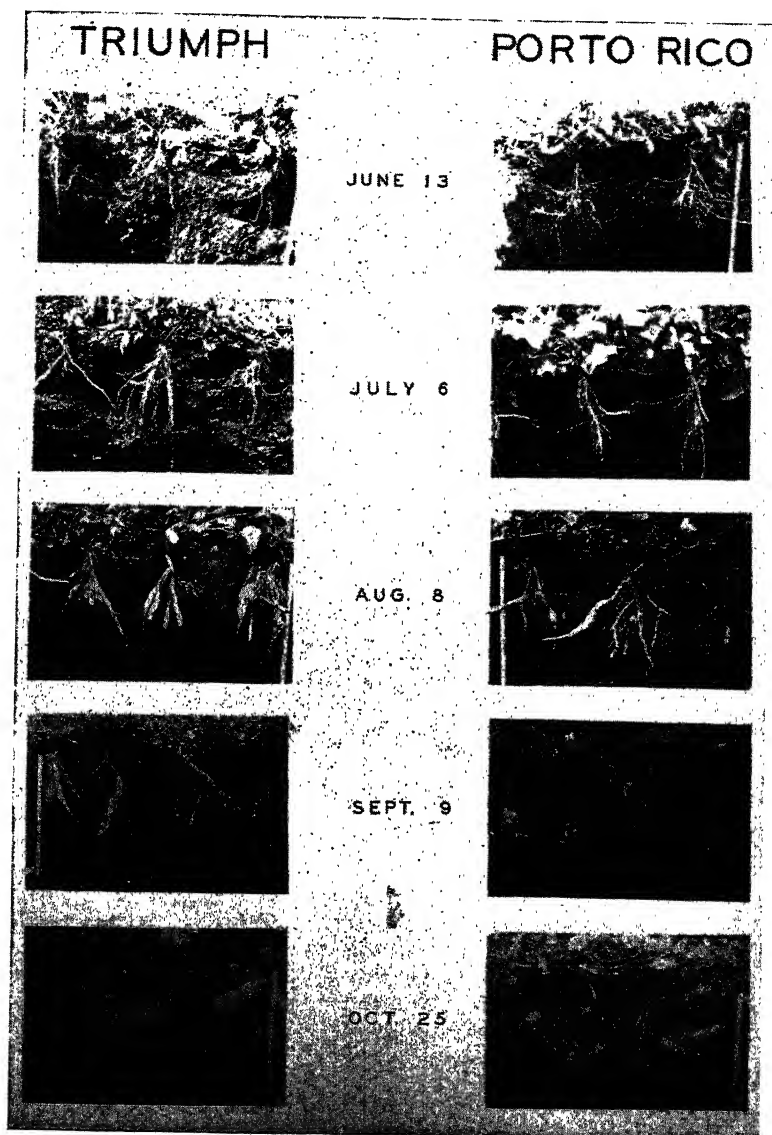


FIG. 1. Photographs showing the seasonal development of Triumph and Porto Rico sweetpotato storage roots in Ocklocknee sandy loam during 1944.

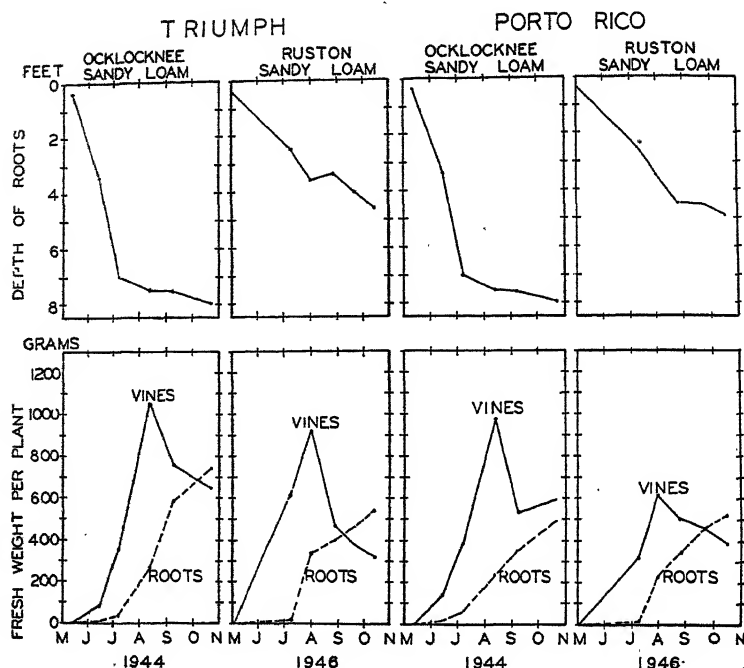


FIG. 2. The depth of the fibrous roots and the average fresh weight of the vines and storage roots of Triumph and Porto Rico sweetpotato plants on two soil types at different times of the season.

167 days after transplanting, and at that time they were found to have reached a total depth of 96 inches.

This study suggested that there is a considerable influence of soil moisture on leaf shedding as well as on yield. Leaf shedding probably occurred in this Ocklocknee field because of insufficient soil moisture in the upper 40 inches, where most of the roots were located. The soil down to this depth was hard to dig and appeared dry on September 8 and October 23. However, the soil below 40 inches seemed to be moderately high in moisture, but there were only a few scattered roots in this soil area. The plants were thus unable to utilize the ample water available at these greater depths.

#### ROOT DEVELOPMENT IN RUSTON SANDY LOAM

For the study in Ruston soil, Triumph sprouts were transplanted near Ellisville, Mississippi, on April 29, 1946, and Unit I Porto Rico sprouts at Poplarville, Mississippi, on April 30, 1946. The fertilizer, consisting of plant nutrients equal to 80 pounds per acre each of N,  $P_2O_5$ ,  $K_2O$ , and CaO, 40 pounds  $MgO$  and 15 pounds of borax, had been applied the same day within each side of the ridges as the land was prepared. The sprouts were set by hand 1 foot apart in the beds which were 42 inches apart. The root systems were examined as was

done in 1944 in Ocklocknee soil, except that the trenches were dug at right angles to the rows.

The photographs in Fig. 3 show the appearance of the storage roots of both varieties at different times of the year, and Fig. 2 shows graphically the seasonal changes in the depth of the fibrous roots and the fresh weights of the vines and storage roots.

The first examination of the Triumph roots made on July 11, 72 days after transplanting, showed that they had attained a depth of 32

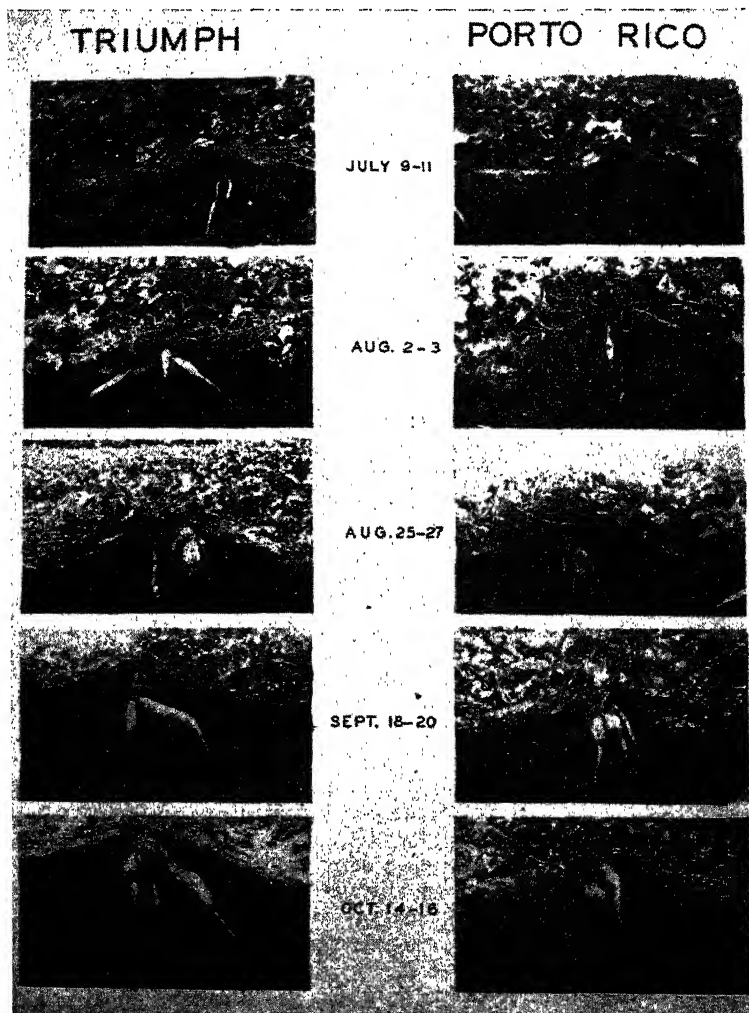


FIG. 3. Photographs showing the seasonal development of Triumph and Porto Rico sweetpotato storage roots in Ruston sandy loam during 1946.

inches in the normal soil. Where burned-out stumps from the original forest were encountered, the depth was greater, being 48 inches in one case. As is seen in Fig. 3, the storage roots were small at this time. Fibrous roots were abundant in the top soil but were only scattered in the subsoil, especially at the greater depths. The Porto Rico roots were examined 2 days later and the same distribution as well as depth was observed as those of the Triumph.

The next examination was made of Triumph on August 2, 94 days after transplanting, and of Porto Rico August 5, 97 days after transplanting. Roots had now attained a depth of 42 inches for both varieties. Root growth was good in the top soil but poor in the subsoil, and vines were growing vigorously at the time.

The Triumph roots were again examined on August 25, 117 days after transplanting, following a period of dry weather. Leaf shedding in this field was excessive and had caused a marked decrease in vine weight as shown by the curve in Fig. 2. The roots were 39 inches deep, and the distribution had not changed since the previous examination. The vines of Porto Rico were growing vigorously on August 27 apparently because of adequate rain at the Poplarville location. Roots of this variety were approximately 40 inches deep, although one root was found as deep as 54 inches.

On September 18 and 20, 141 and 143 days after transplanting, leaf shedding was very severe with both varieties because of dry weather. The top soil of both fields where most of the roots were located, was hard and dry, while the subsoil apparently contained ample moisture. Very few roots were present in the subsoil to make use of it. The maximum depth of fibrous roots of both varieties at this examination was about 48 inches.

The Triumph roots were examined for the last time on October 14, 167 days after transplanting. At this time fibrous roots were found to be 54 inches deep in the normal subsoil, but there were 24 to 30 inches deeper where an old stump had been burned. Fibrous roots, likewise, developed abundantly when they followed channels of decaying tree roots in the subsoil. This can be seen in Fig. 3 for the Triumph variety on September 18. The roots of the Porto Rico were found to be 64 inches deep on October 16, although 57 inches appeared to be the more common total depth of root penetration.

The characteristic fibrous root development of the sweetpotato on Ruston sandy loam soil appears from these studies to be abundant in the top soil and sparse in the subsoil. Fibrous roots are better developed immediately beneath the top soil than they are at greater depths. Very good root development does occur in the subsoil when fertility is sufficient, such as where stumps and roots had burned or rotted. Such locations, however, represent only a very small part of the whole mass of subsoil. The sparse root development in the subsoil makes the plants quickly susceptible to the effects of dry weather. Short periods of dry weather resulted in a very great leaf shedding on both varieties growing in Ruston soil in 1946. The top, darker colored soil, which contained most of the roots, was rapidly depleted of water, while the subsoil still appeared to contain ample water for plant growth,

but the plants had only a few scattered roots in this area. It is believed that the loss of leaves is doubly detrimental to the yield of storage roots of the sweetpotato. In the first place, a loss of starch producing organs occurs and, in the second place, new leaves must be formed from starch and sugar reserves already stored in the plant. The amount of any reduction in yield due to leaf shedding is not known, but it is believed to be considerable.

#### RELATION BETWEEN SOIL TYPE AND ROOT DEVELOPMENT

Root distribution in the two soil types differed considerably. In the Ocklocknee sandy loam the roots were most abundant in the top 12 inches, but were fairly well developed to a depth of 40 inches. In the Ruston sandy loam, they were abundant only in the top 6 to 10 inches of soil and were not abundant in the subsoil, especially at greater depths. The chemical data presented in Table I show that the surface soil and subsoil of the Ocklocknee were higher in nutrients than those of the Ruston sandy loam. The authors are not able to explain why fibrous roots did not develop better than was observed below a depth of 40 inches in the Ocklocknee soil. It is believed, however, that a deficiency of nitrogen at these greater depths limited the root growth.

The chemical analysis of the soils shown by the data in Table I indicate that several factors may have contributed to the relatively poor root development in the Ruston subsoil. It is noted that calcium in the subsoil was low in relation to magnesium. The roots, therefore, may have had insufficient calcium. Potassium was lower in the subsoil than in the top soil, and phosphorus was very deficient in the subsoil.

The most significant observation in these tests was the very great loss of leaves from the Triumph plants between August 2 and August 26 in 1946 on Ruston soil. These results were clearly associated with the dry weather that occurred between these two dates. Leaves, also, were observed to drop from Triumph plants growing on the Ocklocknee soil in 1944 during periods of dry weather, but the loss was much less than that which occurred on Ruston. The differences in the results on the two soils seem to have been due to the difference in the abundance of roots in the subsoil, but may also have been due in part to their differences in the water holding capacity. The results with the Porto Rico variety was less clear than those with the Triumph. Rainfall was not markedly limiting for the plants growing on Ruston soil until in September. Nevertheless, the predominately shallow fibrous root development suggested extreme sensitivity of plants growing in Ruston to dry weather. It would seem that root distribution in Ocklocknee would be preferable to that in Ruston during periods of dry weather, but abundant root growth at still greater depths would be more desirable under drouth conditions.

#### SUMMARY

The results of this study tend to explain why sweetpotatoes are usually more quickly susceptible to drouth when growing on the

lighter sandy loam soils than when they are growing on the heavier soils. The results suggest that luxuriant vine growth, associated with heavy applications of fertilizer, might actually be detrimental, especially in dry weather. With a limited supply of available soil moisture, large rapidly transpiring plants would deplete the soil moisture faster than smaller plants. This behavior may explain why a yield response in sweetpotatoes due to fertilizer may be indicated at some time during the growing season, but may have disappeared by the time of the normal harvest period.

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# Effect of Storage Temperatures on the Sprouting of Four Varieties of Sweetpotatoes

By J. S. COOLEY and L. J. KUSHMAN, *U. S. Department of Agriculture, Beltsville, Md.*

THE investment in seed stock from which sweetpotato plants are grown is considerable. From 5 to 10 bushels of roots are required to give enough plants to set an acre of sweetpotatoes. Any storage treatment, therefore, that affects the yield of plants is correspondingly of economic importance.

Sprouting was one of the tests used for evaluating certain treatments in storage experiments with sweetpotatoes for market conducted at the Plant Industry Station, Beltsville, Maryland. The data obtained in these storage experiments should have additional application in the storing and handling of seed stock for bedding.

The only report noted in the literature, on the effect of storage temperatures on sweetpotato sprout production is the work of Edmond (1). He found that exposing seed stock of Porto Rico sweetpotatoes to 40 degrees F for 7 days, and also for 14 days caused a decreased yield of plants per bushel of roots. This short-time chilling also increased rotting in the plant bed.

The varieties used in the present experiments were Nancy Hall, Porto Rico, Maryland Golden, and Orange Little Stem. They were grown in the vicinity of Beltsville, Maryland, were dug in October before frost, and placed under curing conditions the day they were dug.

TABLE I—NUMBER OF SPROUTS AFTER THREE WEEKS UNDER CONDITIONS FOR SPROUTING

Storage Temperature (Degrees F)	No. Roots Bedded	Total Wt. Roots (Pounds)	No. Sprouts Above Surface of Sand	No. Sprouts Below Surface of Sand	Ave No. Sprouts Per Root		Ave No. Sprouts Per Pound	
					Above Surface	Below Surface	Above Surface	Below Surface
Nancy Hall								
50	7	1.4	7*	23*	1.0	3.3	0.5	1.6
55	7	1.9	70	103	10.0	14.7	36.8	54.2
60	7	2.6	104	110	14.9	15.7	40.0	42.3
Maryland Golden								
50	9	2.4	1**	49**	0.1	5.4	0.4	20.4
55	8	2.0	52	139	6.5	17.4	26.0	69.5
60	8	2.1	84	124	10.5	15.5	40.0	59.0
Orange Little Stem								
50	6	1.1	7†	13†	1.2	2.2	6.4	11.8
55	10	2.7	131	240	13.1	24.0	48.5	88.9
60	10	2.7	127†	232†	12.7	23.2	47.0	85.9
Porto Rico								
50	8	2.4	102	182	12.8	22.8	42.5	75.8
55	9	1.7	95	176	10.6	19.6	55.9	108.5
60	8	2.8	112	193	14.0	24.1	40.0	68.9

\*Five rotten roots, 1 dormant root.

\*\*Four rotten roots, 4 dormant roots.

†Four rotten roots, 1 dormant root.

‡One partly rotten root, 1 dormant root.





FIG. 1. Effect of storage temperatures in the sprouting of sweetpotatoes. Lower: Orange Little Stem, Porto Rico, Nancy Hall and Maryland Golden sweetpotatoes stored at 55 degrees F for 7 months then held at sprouting conditions for 3 weeks. Upper: Orange Little Stem, Porto Rico, Nancy Hall and Maryland Golden sweetpotatoes stored at 50 degrees F for 7 months then held at sprouting conditions for 3 weeks.

The curing consisted in holding for 10 days at 85 degrees F, and a humidity of about 78 per cent of saturation. The same curing treatment was given to all varieties. At the expiration of the curing period the roots were placed at the required temperatures, the humidity being kept at about 85 per cent of saturation in each instance.

Three storage temperatures were used, 50, 55, and 60 degrees F. The temperature of each storage room was accurately controlled to within 0.5 of a degree F throughout the storage period.

### EXPERIMENTAL RESULTS

The storage period was terminated on May 7, 1947, about 7 months from the time the roots were dug. At this time the final record on rots and keeping quality was made, and this will be reported in a future publication. The rotten roots were discarded and from the remainder six or eight apparently healthy bedding-size roots were given sprouting conditions by being placed in moist sand and held in a storage room at 85 degrees F for 3 weeks (May 8 to May 29). The results are recorded in Table I.

The sweetpotatoes that were stored at 50 degrees F, and then subjected to good sprouting conditions, showed marked variety variation in their ability to sprout and also in their susceptibility to rotting during the sprouting operation. The data indicate that a storage temperature of 50 degrees F is too low for optimum sprouting of Orange Little stem, Nancy Hall, and Maryland Golden (Fig. 1); but Porto Rico stored at 50 degrees F gave good sprouting. All four of the varieties sprouted satisfactorily after storage at 55 or 60 degrees F. This sprouting test as well as other tests indicates that Porto Rico is more tolerant of storage at 50 degrees than are the other varieties tested; but there is evidence that 50 degrees is below the optimum for that variety. Nearly all of the rot that developed during the sprouting period occurred in material that had been stored at 50 degrees. Also, most of the dormant (non-sprouting) roots were among those stored at 50 degrees.

The data here presented indicate that storage temperature has a marked effect upon the sprout production of apparently healthy sweetpotatoes. This may help to explain certain instances of bedding failures.

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## Natural Self-Pollination in Cantaloupes<sup>1</sup>

By S. S. IVANOFF, *Texas Agricultural Experiment Station,  
Substation 19, Winter Haven, Texas*

NATURAL self-pollination was observed to occur very frequently in pure lines of cantaloupes in the breeding plot at Winter Haven, Texas. Seed of many open-pollinated individual fruits saved from pure lines seemed to run true to type. Jones and Rosa (1) reported that from 5 to 15 per cent of the seed of hermaphroditic-flowered varieties may be cross-pollinated where different varieties are grown in adjoining rows. A trial was made at Winter Haven in 1942-1943, to determine the extent of self-pollination of individual isolated plants when surrounded on all sides by plants of another variety flowering at the same time.

Four vines of inbred cantaloupes with recessive green flesh fruit color were grown in a block of Honey Ball plants with dominant salmon flesh. The salmon flesh color, characteristic of the fruits of the F<sub>1</sub> hybrid between these two cantaloupes, was used in the 1943 season to determine whether cross-pollination under the conditions of the trial had occurred during the previous season. Some of the ovules of an ovary may be fertilized by pollen from the same plant, in which case the resulting seed will give rise to a plant bearing green-flesh fruits only. On the other hand, ovules fertilized by pollen from the salmon-flesh variety will form seed which will grow to a plant yielding fruits with salmon flesh. The number of germinable seeds in a single fruit of the commonly grown varieties varies from about 300 to 400 and there is an opportunity for some of them to be formed as a result of cross-pollination.

Previous tests have shown that covering hermaphroditic flowers in a manner to exclude all insects seldom resulted in fruit formation. This probably is because the anthers dehisce on the side opposite the stigma and the sticky pollen, deposited at the base of the corolla, is prevented from reaching the stigma across the closely packed anthers. Most pollination evidently is performed by insects, particularly honey bees, but others, such as flower thrips, may also play a part.

The block of the salmon-flesh melons in this trial consisted of six rows 120 feet long and 6 feet apart, the plants spaced 2 feet within the row. In this area were grown four green-flesh melon plants spaced from 30 to 40 feet from each other. All vines eventually became interwoven and during anthesis the planting appeared as a solid mass of growth, covering completely the ground between the rows. The green-flesh vines were covered by the leaves of the Honey Ball variety which blossomed profusely and for a long time. These two varieties, like most of the commonly grown cantaloupes in the United States, are andromonoecious, bearing staminate and hermaphroditic flowers on the same vine.

At the end of the season 21 fruits were harvested from the four

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green-flesh vines and some of the seed of each fruit were marked as a separate line and planted in the following season. From 4 to 35 plants were raised from the seed of each fruit, with a total of 383 plants. The small number of plants of some of these single-fruit-derived lines was the result of unfavorable growth conditions during the first part of the season. At the end of the second season fruits from each vine were cut, and judging by the color of the flesh, the degree of self-pollination for each line was determined.

The per cent of self-pollination for the four vines was 98.6, 75.7, 0, and 0, respectively. The self-pollination for the first two vines was very high, while the last two vines, with a total of five fruits, produced all hybrid plants. The great difference in self-pollination among the four green-flesh vines is probably due to some special conditions during pollination.

Table I shows the detailed results of the trial, from which it may be seen that (a) self-pollination or inbreeding within certain fruits reached 100 per cent even when all opportunities for cross-pollination were provided, and (b) the extent of self-pollination among the seed

TABLE I—EXTENT OF NATURAL SELF-POLLINATION IN FOUR CANTALOUPE VINES OF A GREEN-FLESH VARIETY (COLOR RECESSIVE) EXPOSED ON ALL SIDES TO POSSIBLE POLLINATION FROM A SALMON-FLESH VARIETY (COLOR DOMINANT). SELF-POLLINATION DETERMINED BY DOMINANT COLOR OF FRUIT FLESH IN THE FOLLOWING SEASON

No. Fruits Harvested From Each Exposed Vine (1942 Season)	No. Plants Grown From Each Fruit From Exposed Vines in the Following Season	No. Self-Pollinated Fruits Determined by Green Flesh Color	Per Cent Self-Pollinated Fruits
<i>Vine No. 1</i>			
1	14	14	100.0
1	14	14	100.0
1	20	19	95.0
1	9	9	100.0
1	19	19	100.0
5	76	75	98.6 Ave.
<i>Vine No. 2</i>			
1	11	9	81.8
1	19	4	21.0
1	14	12	85.7
1	4	4	100.0
1	35	35	100.0
1	24	4	16.6
1	33	32	96.9
1	29	27	93.1
1	19	19	100.0
1	12	12	100.0
1	14	4	28.5
11	214	162	75.7 Ave.
<i>Vine No. 3</i>			
1	4	0	0.0
<i>Vine No. 4</i>			
1	27	0	0.0
1	16	0	0.0
1	23	0	0.0
1	23	0	0.0
4	89	0	0.0 Ave.

samples varied extremely, from 0 to 100 per cent. In eight of the single-fruit-derived lines all of the plants were of self-pollinated origin, five lines had all fruits of hybrid nature, and the remaining eight lines had fruits of mixed origin varying from 16.6 to 96.9 per cent of inbred fruits.

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## Results on the Control of Rootknot Nematode in Vegetable Plant Beds

By S. C. DORMAN,<sup>1</sup> *Shell Development Company, Emeryville, Calif.* and P. A. MINGES, *University of California, Davis, Calif.*

IN California many good soils used for vegetables have become infested with rootknot nematode through the introduction of this pest on infested transplants. Also severe crop losses occur each year because young plants become infested in the plant bed and the nematode gets such an early start that the plant is seldom productive. The only solution to the problem has been to select plant bed sites that were free of nematode, but this frequently has been a difficult thing to do.

A new soil fumigant containing chlorinated propylenes and known under the registered trademark D-D<sup>2</sup> has shown promise as a nematocide under a rather wide range of field conditions. Thus Carter (1) has reported that its use resulted in improved growth of pineapple in Hawaii, Pinckard (2) found it highly effective for squash in Mississippi, and Parris (3) obtained promising results for tomatoes in Virginia. The tests reported herein were conducted in 1945 to explore the possibilities of using this material under the special conditions involved in producing vegetable transplants.

### PLAN AND METHODS

A site moderately infested with rootknot nematode was selected on Yolo fine sandy loam near Davis. Tomatoes and cabbage were selected as test crops as they represented warm and cool season crops which are usually transplanted.

In field fumigation a few nematodes may be left without causing appreciable losses, but in plant beds it is highly desirable to obtain complete control if possible. Thorne (4) noted that it is difficult to kill nematodes in the surface 2 or 3 inches of soil where aeration is good and a fumigant escapes easily. Godfrey and Young (5) pointed out that this problem is serious with chloropicrin and that this material did not become valuable as a soil fumigant until gas tight covers or water seals were developed for confining the fumes in the soil. Hannesson, Raynor and Crafts (6) report that "it is difficult to retain a high vapor density of carbon disulfide in the top 4 inches of soil". In an effort to obtain control of the nematode in the surface soil layers dry and water emulsion applications were tested both singly and in combination. It was thought that in the combination treatment the dry application might kill the deep nematodes and the water emulsion those near the surface. The treatments were as follows:

1. Check (untreated)
2. D-D 400 pounds (40 gallons) per acre rate—applied dry at 5 inch depth and 12 inch spacing; (3.47 ml per injection)
3. D-D 400 pounds per acre rate—emulsifiable form applied in water (125 ml per plot in 56 gallons water)

<sup>1</sup>Present address Shell Oil Agricultural Laboratory, Modesto, California.

<sup>2</sup>Supplied by Shell Chemical Corporation, San Francisco.

4. D-D 200 pounds per acre rate — applied dry at 8 inch depth and 12 inch spacing (1.7 ml per injection)  
200 pounds per acre rate — emulsifiable form applied in water (62.5 ml per plot in 22.5 gallons water)

Each plot was 6 feet square or 36 square feet in area. Each treatment was replicated three times thus giving a total of 12 plots in the experiment. Levees about 6 inches high were built around the plots receiving the water application. The emulsion of D-D and water was vigorously agitated before adding it to the plots. Sufficient water was used in treatment 3 to insure penetration to a depth of  $2\frac{1}{2}$  feet. In treatment 4 the dry application was made first and then the water emulsion added. In treatment 2 the plots were sprinkled after application to seal over the soil. A Mack weed gun was used to make the dry injections.

The plants were grown in open beds without frames or covers. The plots were treated on March 20 and seeded on April 6, an interval of 17 days. The cabbage started emerging on April 16 and the tomatoes on April 23. The roots were examined on May 31 and again on September 5. The soil temperature at the time of treatment was 52 degrees F and the soil moisture was at field capacity except for the surface 2 inches which was slightly drier.

At the first examination of the roots on May 31 approximately 40 plants were carefully dug from each plot, preserving as much of the root system as possible. After carefully washing them the roots of each plant were floated in water in a white bottom, shallow pan to permit close observation.

The roots were classified according to nematode infestation as indicated by presence of knots or galls as follows: 1, clean; 2, slight — one to five individual galls per plant; 3, moderate — more than five individual galls; and 4, severe — included all plants with roots showing coalescing of the galls or worse.

After the first examination some plants were removed for transplanting to field plots with the remaining plants kept watered to permit a second examination. This was done on September 5 with the same system of sampling being followed except that only 17 tomato plants and only 6 to 10 cabbage plants were examined per plot.

## RESULTS

The seedlings emerged at about the same time on all of the plots. However, it soon became evident that the stand of plants and growth was better on the treated than on the check plots. By May 31 the plants on the check plots were about two-thirds as large as those on the treated and aside from the nematode infestation would have made rather poor transplants (Fig. 1).

A summary of the data from the May 31 examination is given in Table I.

The data show that the roots of plants from the check plots were seriously infested with nematode and even if used in fields free of nematode probably would have given poor yields. Samples from the



FIG. 1. Plots of tomato and cabbage plants. Plants grown in soil treated with D-D (foreground); plants grown in untreated soil (background).

treated plots showed a rather high percentage of clean plants, yet a few plants from each treatment showed some gall formation. The treatments using all or part of the D-D in water appeared to be slightly superior to treatment 2 in which all of the material was applied dry.

TABLE I—THE PERCENTAGE OF TOMATO AND CABBAGE PLANTS IN THE FOUR CLASSES OF NEMATODE INFESTATION ON THE MAY 31 EXAMINATION. THESE FIGURES ARE BASED ON A TOTAL OF 100 TO 120 PLANT SAMPLES FROM THREE REPLICATIONS

Treatments	Tomatoes (Per Cent)				Cabbage (Per Cent)			
	Clean	Slight	Mod.	Severe	Clean	Slight	Mod.	Severe
1. Check.....	1.6	19.2	30.0	49.2	3.8	25.5	34.9	35.8
2. D-D- dry injections.....	87.5	12.5	0	0	92.8	7.2	0	0
3. D-D- in water.....	95.5	3.6	0.9	0	90.8	9.2	0	0
4. D-D $\frac{1}{2}$ dry; $\frac{1}{2}$ in water	95.5	4.5	0	0	96.3	3.7	0	0

The summary of the data from the September 5 examination is given in Table II.

The data for tomatoes show that the nematode infestation increased somewhat during the interval between examinations, but relative positions of the treatments remained in line with the first examination. The data for cabbage show an improvement in the nematode infestation, but there were actually too few plants left in the beds to give an accurate sampling.



TABLE II.—THE PERCENTAGE OF TOMATO AND CABBAGE PLANTS IN THE FOUR CLASSES OF NEMATODE INFESTATION ON SEPTEMBER 5 EXAMINATION. FIGURES FOR TOMATOES BASED ON A TOTAL OF 50 TO 54 SAMPLES FROM THREE REPLICATIONS; CABBAGE ON 17 TO 23 SAMPLES

Treatments	Tomatoes (Per Cent)				Cabbage (Per Cent)			
	Clean	Slight	Mod.	Severe	Clean	Slight	Mod.	Severe
1. Check.....	0	10.3	6.9	82.8	30.4	13.0	34.8	21.8
2. D-D dry injection.....	74.0	26.0	0	0	94.1	5.9	0	0
3. D-D in water.....	88.0	12.0	0	0	100.0	0	0	0
4. D-D $\frac{1}{2}$ dry; $\frac{1}{2}$ in water	88.9	11.1	0	0	100.0	0	0	0

Plants from the treated plots were transplanted on May 31 into untreated infested soil and into infested soil that had been treated with D-D or ethylene dibromide. A root examination of these plants on September 5 showed rather severely infested plants in the untreated soil but practically no evidence of gall formation in the treated soil. The transplants in the untreated soil grew well at the start indicating that a clean root system on transplants is beneficial in overcoming the effects of nematodes in the soil.

#### SUMMARY

The soil fumigant, D-D, gave fairly good control of rootknot nematode in this plant bed test, and showed promise for use by growers who have difficulty in locating plant bed sites that are free or relatively free of nematode. Since the material evidently does not completely eradicate the nematode, at least with present methods of application, it cannot be regarded as an absolute safeguard against infested plant beds. Therefore, growers should not rely solely on soil fumigation to prevent the introduction of nematode into clean fields.

The water emulsion method of applying the material appeared to be slightly superior to the dry injection method, probably because it was more effective in killing nematodes in the upper 2 or 3 inches of soil.

Rates of application of the soil fumigant were not compared, but it is believed that lower rates would be less desirable since the cost factor is not generally important in plant bed treatment, and lower rates might prove less effective. A higher rate might give slightly more effective control but the danger of a detrimental effect on germination and plant growth must be considered when heavy dosages are used.

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## Effects of Fertilizer and Method of Application of Supplementary Nitrogen on the Yield of Turnip Greens for Canning<sup>1</sup>

By H. L. COCHRAN, *Pomona Products Company, Griffin, Ga.*

**T**URNIP (*Brassica rapa* L.) greens have long been grown as a garden vegetable, and consumed as a favorite boiled dish by people in the South. More recently, however, this crop has been grown commercially for canning, and sold in competition with other canned greens in certain sections of the United States. The characteristic flavor and relatively high nutritive value of turnip greens (1, 2, 3, 4) have served to increase their popularity as a canned vegetable.

In general, production in Georgia is concentrated in two more or less distinct areas: the central section and the southern section. In the central section, well-drained bottom lands are used where the seed is sown broadcast and the soil is irrigated; and in the southern section where upland soils are used and the crop is grown in rows without the use of irrigation.

Growers in the central bottom land area have heretofore followed no systematic fertilizer program. Some apply large quantities of complete mixtures, others apply relatively small quantities. Some apply supplementary nitrogen with the fertilizer while others use it as a top dressing when the plants are in the seedling stage. To develop a satisfactory and efficient fertilizer program for this crop, cooperative tests were initiated in the spring of 1944. The pertinent results of two year's work are presented herewith.

### MATERIALS AND METHODS

The soil is classed as a Cecil sandy clay loam, with an average pH of 6.0, and had grown four crops of turnip greens from 1940 to 1943 inclusive, the four years immediately preceding the initiation of the experiment. Chemical analysis showed the soil to contain sufficient organic matter to give it a good physical condition, and a fair natural fertility.

The Shogoin variety was used exclusively in this work as it is the principal one grown for canning in central Georgia. The land was plowed in the late fall, and double disced and dragged just before planting time in the early spring. The fertilizer treatments involved two variables: seven different rates of applying an 8-8-6 mixture, and two different times of applying supplementary nitrogen. The experiment was set up in three randomized blocks, each treatment was replicated three times, and an individual plot was 25 feet long and 10 feet wide.

The 8-8-6 mixture consisted of 18 per cent nitrate of soda, 20 per cent acid phosphate, and 50 per cent muriate of potash. It was applied

<sup>1</sup>Grateful acknowledgment is made to Dr. J. B. Edmond formerly of the Berry Schools, Mount Berry, Georgia, for his assistance in the statistical analysis of the data, and for helpful suggestions in the preparation of the manuscript.

broadcast and hand raked into the soil. The seven rates of application varied from 1000 to 4000 pounds per acre. The supplementary nitrogen was applied in the form of nitrate of soda at the rate of 150 pounds per acre at two different times (a) with the fertilizer, and (b) as a top dressing when the plants were 2 inches tall.

During both years of this experiment the seed was planted with a hand turned cyclone seeder at the rate of 15 pounds per acre, and covered shallow with a hand rake. Each year planting occurred during the second week in March, and harvesting took place during the second week in April. In order to maintain rapid growth and development water was applied when ever necessary by means of a portable irrigation system equipped with rotary sprinklers.

### RESULTS AND DISCUSSION

The mean yields of the two variables studied in this work are presented in Table I. In the rate test the data show that yields increased

TABLE I—EFFECTS OF FERTILIZER AND METHOD OF APPLICATION OF SUPPLEMENTARY NITROGEN ON THE YIELD OF TURNIP GREENS FOR CANNING

Pounds 8-8-6 Per Acre	Method Used in Applying 150 Pounds Nitrate of Soda Per Acre				Mean Yield Rate Test (Tons Per Acre)	Differences Necessary for Significance	
	Top Dressing		With Fertilizer			Odds 19:1	Odds 99:1
	1944	1945	1944	1945			
1,000	8.1	7.3	7.6	6.6	7.4	0.195	0.292
1,500	9.5	8.3	9.1	7.7	8.7		
2,000	9.6	8.6	9.3	8.2	8.9		
2,500	9.6	8.6	9.4	8.3	9.0		
3,000	9.5	8.6	9.0	8.2	8.4		
3,500	9.5	8.3	8.8	8.1	8.7		
4,000	9.0	8.0	8.4	7.7	8.3		
Mean yield (tons per acre)			Top dressing		8.8	0.104	0.156
Nitrate of soda test			With fertilizer		8.3		
Mean yield (tons per acre)			1944		9.0	0.104	0.156
By years			1945		8.0		

from the 1000 pound to the 2500 pounds per acre application, and decreased from the 2500 pound to the 4000 pounds per acre application. The differences between any two succeeding applications are significant except that between the 2000 and 2500 pounds per acre application which is insignificant. The low yields for the 3000 pounds per acre and succeeding applications are largely due to relatively poor stands. Apparently the large quantities of soluble nitrogen caused many of the young seedlings to die before they reached the surface of the soil. The marked and highly significant difference between the 1000 and 1500 pounds per acre application is of much interest to the grower. The addition of the extra 500 pounds of fertilizer would be a sound investment in terms of cash net returns.

In the nitrogen test the data show that in all 14 comparisons applying nitrogen as a top dressing when the plants were 2 inches tall produced greater yields than applying the same quantity of nitrogen with

the complete fertilizer. The mean difference is highly significant, and shows that under the conditions of this experiment a top dressing of supplementary nitrogen is a more economically sound practice than applying it with the fertilizer. Apparently the addition of supplementary nitrogen as a top dressing when the plants are 2 inches tall, and the use of irrigation when needed, kept the crop in a healthy, growing condition without the development of nitrogen deficiency. Thus, the additional 27 pounds of supplementary nitrogen applied at the time the basic fertilizer application was made becomes in excess of the needs of the crop for at least 2 weeks or longer, and under conditions of heavy rainfall is subject to loss both by leaching and surface runoff.

The data show marked and highly significant differences in yield between the two years. In fact, in all 14 comparisons greater yields were obtained in 1944 than in 1945, due in all probability to more conducive growing weather in the former than in the latter.

#### SUMMARY AND CONCLUSIONS

Experiments were conducted with the Shogoin variety of turnip greens on bottom lands in central Georgia during the spring seasons of 1944 and 1945, to determine the effect of a varying rate of a complete fertilizer, and method of applying supplementary nitrogen on yields of this crop. An 8-8-6 mixture was applied at rates varying from 1000 to 4000 pounds per acre, at increments of 500 pounds per acre, and 150 pounds of nitrate of soda per acre was applied with the fertilizer at the time the land was prepared for planting, and as a top dressing when the plants were 2 inches tall.

Yields of greens increased from the application of 1000 to 2500 pounds per acre of the fertilizer, and decreased from the addition of 2500 to 4000 pounds per acre. The differences in yield are significant between the 1000 pound and the 1500 pounds per acre applications, as well as between the 1500 pound and the 2000 pounds per acre applications, but insignificant between the 2000 pound and the 2500 pounds per acre applications.

Applying supplementary nitrogen as a top dressing when the plants were 2 inches tall produced significantly greater yields than applying it with the fertilizer just prior to planting.

On the basis of these results an effective fertilizer for turnip green growers of central Georgia would be the application of 1500 to 2000 pounds per acre of an 8-8-6 fertilizer a little before planting, and this followed with the addition of 150 pounds per acre of Nitrate of Soda or its equivalent in nitrogen as a top dressing when the plants reach a height of approximately 2 inches.

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## Effect of Root-Trimming, Washing, and Waxing on the Storage of Turnips

By M. H. HALLER, *U. S. Department of Agriculture,  
Beltsville, Md.*

**P**URPLE Top turnips grown on DDT spray plots in a sandy soil at Beltsville, Maryland were used for these investigations. In 1945 the turnips were dug and topped on June 2 and were generally large, crisp, tender, and mild. In 1946 they were dug and topped on May 31 and averaged smaller than in 1945. Turnips from the different spray plots were mixed and given the trimming, washing, and waxing treatments 2 to 3 days after harvest.

In topping the turnips about  $\frac{1}{4}$  inch of the leaf petioles was left. Trimming consisted of cutting off the narrow tap root and all small side roots. In 1945 the roots were washed by immersing them in a tank of cold water. Waxing was accomplished by immersing the roots in the wax emulsions immediately after washing. They were then dried by placing them on a chicken-wire screen in the draft from a large fan. In 1946 the roots were washed in cold water by passing them through a flotation type apple washer. Wax emulsions were applied by means of a waxer in which a froth of the emulsion overflows onto revolving cloths that apply it to the turnips on a roller conveyor under the cloths. Drying was then done by conveying the roots under a series of heat lamps in a drying tunnel. The hot wax treatment consisted in immersing the roots for about one second in hot paraffin (96 per cent paraffin plus 4 per cent of resin) at 255 to 265 degrees F.

In 1945 the turnips were stored in lined bushel baskets at 32 degrees F with high (95+ per cent) and intermediate (85+ per cent) humidity. The intermediate humidity was at a somewhat higher level than planned so that the difference was not so large as intended. In 1946 the roots were stored at two temperatures (32 and 36 degrees) instead of at two humidities.

Each lot (1 bushel in amount) was weighed at the time it was placed in storage and when removed from storage and again after a period at room temperature. In 1945 the roots were held at 32 degrees F for 4 weeks followed by 11 days at 70 degrees. In 1946 they were held at 32 degrees for about 2 weeks, followed by 6 days at 70 degrees.

In 1946 respiratory rates were determined at 70 degrees F by the method previously described (1).

### RESULTS

The weight loss during cold storage and exposure to 70 degrees F after storage is shown in Table I for 1945 and Table II for 1946. Washing had no consistent effect on weight loss, apparently reducing it in 1945 but increasing it in 1946.

The small difference in humidity in 1945 had no appreciable effect on weight loss at 32 degrees F, the average loss at the higher humidity

TABLE I—WEIGHT LOSS AND DECAY IN TURNIPS AS INFLUENCED BY VARIOUS TREATMENTS (1945)

Lot No.	Washed	Wax		Relative Humidity (Per Cent)	Roots Trimmed	Weight Loss:			Decay (Per Cent)
		Kind	Conc.			At 32 Degrees (Per Cent)	At 70 Degrees (Per Cent)	Total (Per Cent)	
1	No	None	—	95	No	1.87	4.73	6.60	30.7
2	No	None	—	95	Yes	1.28	3.65	4.93	20.6
3	No	None	—	85	No	1.82	4.57	6.39	36.3
4	No	None	—	85	Yes	1.86	3.85	5.71	26.9
Mean								5.91	28.6
5	Yes	None	—	95	No	2.05	3.60	5.65	7.8
6	Yes	None	—	95	Yes	1.06	3.16	4.22	7.0
7	Yes	None	—	85	No	2.01	2.89	4.90	11.0
8	Yes	None	—	85	Yes	2.41	3.76	6.17	20.0
Mean								5.24	11.5
9	Yes	Sta-Fresh 810	1-2*	95	No	1.91	3.28	5.19	13.8
10	Yes	Sta-Fresh 810	1-2*	95	Yes	2.15	3.80	5.95	9.6
11	Yes	Sta-Fresh 810	1-2*	85	No	1.84	3.36	5.20	4.2
12	Yes	Sta-Fresh 810	1-2*	85	Yes	1.73	3.06	4.79	7.8
Mean								5.28	7.8
13	Yes	Sta-Fresh 810	1-4	95	No	2.20	4.13	6.33	5.0
14	Yes	Sta-Fresh 810	1-4	95	Yes	2.36	4.07	6.43	11.6
15	Yes	Sta-Fresh 810	1-4	85	No	1.78	3.08	4.86	2.5
16	Yes	Sta-Fresh 810	1-4	85	Yes	1.98	3.68	5.66	12.1
Mean								5.82	7.8
17	Yes	Brytene 489A	1-2†	95	No	1.54	3.96	5.50	4.6
18	Yes	Brytene 489A	1-2†	95	Yes	2.10	3.74	5.84	5.8
19	Yes	Brytene 489A	1-2†	85	No	1.76	3.41	5.17	1.7
20	Yes	Brytene 489A	1-2†	85	Yes	1.81	2.88	4.69	3.0
Mean								5.30	3.7
21	Yes	Brytene 489A	1-4	95	No	1.43	3.42	4.85	8.9
22	Yes	Brytene 489A	1-4	95	Yes	1.89	3.79	5.68	16.3
23	Yes	Brytene 489A	1-4	85	No	1.45	3.48	4.93	4.0
24	Yes	Brytene 489A	1-4	85	Yes	1.69	2.82	4.51	4.6
Mean								4.99	7.2

\*Undiluted Sta-fresh 810 (Food Machinery Corporation) consists of 7 per cent carnauba wax and 5 per cent paraffin, with total solids amounting to 18.5 per cent.

†Undiluted Brytene 489A (Franklin Research Company) consists of 8.1 per cent carnauba wax and 4.4 per cent paraffin, with total solids amounting to 18 per cent.

being 1.82 per cent as compared with 1.84 per cent at the lower humidity.

Likewise the difference in storage temperature in 1946 had no significant effect on weight loss, the average loss being 2.91 per cent at 32 degrees F and 2.63 per cent at 36 degrees F. With the same relative humidity a greater loss would be expected at the higher temperature because of its greater saturation deficit.

Trimming the roots also had no significant effect on weight loss. The average total loss of the untrimmed (check) turnips was 5.46 and 6.66 per cent in 1945 and 1946, respectively, whereas the corresponding trimmed lots lost 5.36 and 6.27 per cent.

Coating the turnips with the various wax emulsions did not appreciably retard weight loss either year as is shown by the data in Tables I and II. However, dipping the turnips in hot melted paraffin in the 1946 season gave the roots a relatively heavy coating that greatly retarded loss of moisture. The average total loss for this treatment was only 1.4 per cent as contrasted with 6.5 to 7.5 per cent for the lots waxed with the wax emulsions (Table II). These results are not entirely in agreement with those of Platenius (2) who obtained nearly 50 per cent reduction in shrinkage of turnips with

TABLE II—WEIGHT LOSS AND DECAY IN TURNIPS AS INFLUENCED BY VARIOUS TREATMENTS (1946)

Lot No.	Washed	Wax		Temp of Storage Degrees F)	Weight Loss:				Decay (Per Cent)	Breakdown (Per Cent)	Sprouted (Per Cent)
		Kind	Conc.		Roots Trimmed	At 32 Degrees (Per Cent)	At 70 Degrees (Per Cent)	Total (Per Cent)			
1	No	None	—	32	No	3.4	4.4	7.5	0	45	72
2	No	None	—	32	Yes	3.2	4.1	7.3	3.4	10	76
3	No	None	—	36	No	2.6	4.0	6.6	0	35	80
4	No	None	—	36	Yes	3.2	4.7	7.9	0	30	83
		Mean	—	—	—	—	—	7.33	0.8	30	78
5	Yes	None	—	32	No	4.4	4.3	8.7	0	30	68
6	Yes	None	—	32	Yes	3.5	3.9	7.4	1.1	25	71
7	Yes	None	—	36	No	4.0	3.9	7.9	0	45	76
8	Yes	None	—	36	Yes	3.9	5.1	9.0	1.0	75	77
		Mean	—	—	—	—	—	8.25	0.5	44	73
9	Yes	Sta-fresh 810*	1-1	32	No	3.7	3.8	7.5	5.2	45	73
10	Yes	Sta-fresh 810*	1-1	32	Yes	3.6	4.8	8.4	0	40	68
11	Yes	Sta-fresh 810*	1-1	36	No	3.7	4.1	7.8	0	35	67
12	Yes	Sta-fresh 810*	1-1	36	Yes	3.6	3.5	7.1	1.1	40	75
		Mean	—	—	—	—	—	7.70	1.6	40	71
13	Yes	Sta-fresh 860**	1-1	32	No	2.9	4.3	7.2	0	50	79
14	Yes	Sta-fresh 860**	1-1	32	Yes	3.0	3.4	6.4	1.1	20	67
15	Yes	Sta-fresh 860**	1-1	36	No	3.0	4.2	7.2	1.0	45	73
16	Yes	Sta-fresh 860**	1-1	36	Yes	2.5	4.0	6.5	0	40	68
		Mean	—	—	—	—	—	6.83	0.5	39	72
17	Yes	Brytene 333B†	1-1	32	No	3.0	4.9	7.9	0	45	62
18	Yes	Brytene 333B†	1-1	32	Yes	2.5	3.5	6.0	0	25	72
19	Yes	Brytene 333B†	1-1	36	No	2.4	4.1	6.5	1.0	35	69
20	Yes	Brytene 333B†	1-1	36	Yes	1.5	4.3	5.8	1.0	35	79
		Mean	—	—	—	—	—	6.55	0.5	35	70
21	Yes	S/V PD 351G‡	1-1	32	No	3.7	4.7	8.4	0	55	62
22	Yes	S/V PD 351G‡	1-1	32	Yes	2.7	4.2	6.9	0	40	72
23	Yes	S/V PD 351G‡	1-1	36	No	2.8	4.1	6.9	0	30	69
24	Yes	S/V PD 351G‡	1-1	36	Yes	2.6	4.1	6.7	0.9	30	83
		Mean	—	—	—	—	—	7.23	0.2	39	72
25	Yes	Hot paraffin	100 per cent	32	No	0.7	1.2	1.9	0	25	22
26	Yes	Hot paraffin	100 per cent	32	Yes	0.4	0.9	1.3	2.3	25	20
27	Yes	Hot paraffin	100 per cent	36	No	0.8	0.5	1.3	0	13	10
28	Yes	Hot paraffin	100 per cent	36	Yes	0.2	0.9	1.1	2.0	30	12
		Mean	—	—	—	—	—	1.4	1.1	24	16

\*See footnote \* of Table I.

\*\*Sta-fresh 860 (Food Machinery Corporation) is a wax emulsion similar to their No. 810 but with a higher proportion of carnauba wax.

†Undiluted Brytene 333B (Franklin Research Company) emulsion consists of 2.8 per cent carnauba wax and 11.3 per cent paraffin with total solids amounting to 24 per cent.

‡Undiluted S/V PD 351G (Socony-Vacuum Company) emulsion consists of 14.5 per cent high melting point vegetable (carnauba) waxes with total solids amounting to 18 to 20 per cent.

applications of wax emulsions. He found much greater reduction in shrinkage of rutabagas when dipped in hot paraffin. Truscott and Thomson (3) describe the treatment of rutabagas (turnips) with hot, melted paraffin and state that this treatment has been found more suitable for turnips than wax emulsions.

In the 1945 season the turnips were generally crisp and mild in flavor after 4 weeks at 32 degrees F storage. There was no shriveling in any of the lots and no decay. After holding at 70 degrees for another 11 days the turnips were moderately pithy. There was still no shriveling in any of the lots and no perceptible difference in appearance between the waxed and unwaxed lots. By this time, however, considerable decay had developed in some lots (Table I). It consisted of a fairly firm decay with practically no discoloration but considerable greyish mold on the surface. It was most severe in the unwashed lots in which it averaged 28.6 per cent, whereas the washed



lots averaged 11.5 per cent and the washed and waxed lots averaged from 3.7 to 7.8 per cent. The decay generally entered at the stem end and was not increased by cut or injured surfaces as the trimmed lots did not have significantly more decay (average 11.8 per cent) than the untrimmed lots (average 10.5 per cent).

In the 1946 season the turnips were firm and crisp after 2 weeks at 32 and 36 degrees F. There were slight discolorations from bruising and abrasions. Lots waxed with wax emulsions did not look or feel differently from unwaxed lots. Lots treated with hot paraffin had a glossy, wax finish but the color seemed somewhat dulled. After holding at 70 degrees for 6 days following cold storage there was no appreciable decay (Table II). All lots felt firm and appeared solid but on cutting showed punkiness and in some instances flesh breakdown consisting of flesh discoloration and open spaces in the flesh. Twenty roots from each lot were cut and the percentage of breakdown was determined from them. There seemed to be no consistent difference in the breakdown attributable to temperature or waxing treatment, although the lots treated with hot paraffin averaged the least. There was also considerable sprouting of new leaves and development of new roots. In the lots treated with hot paraffin there were no new roots formed and only 16 per cent were sprouting, whereas in the other lots slight to much root formation occurred and 70 to 78 per cent were sprouting. There was no significant difference in sprouting or rooting among the lots treated with the different wax emulsions and the nonwaxed lots.

The effect of the different waxing treatments on the respiratory activity of turnips at 70 degrees F is shown in Table III. The wax emulsions with high proportions of paraffin (Sta-fresh 810 and Bry-

TABLE III—RESPIRATORY ACTIVITY ( $\text{CO}_2$  EVOLVED) OF TURNIPS  
AT 70 DEGREES AS INFLUENCED BY WAX COATINGS

Wax Coating	Washed	$\text{CO}_2$ (Mg Per Kg Hr)
None	No	54.6
None	Yes	56.1
Sta-fresh 810	Yes	47.5
Sta-fresh 860	Yes	53.1
Brytene 333B	Yes	46.8
S/V PD 351G	Yes	56.9
Hot paraffin	Yes	25.2

tene 333B) apparently reduced the evolution of  $\text{CO}_2$  slightly but the other wax emulsions did not. The heavy coating of melted paraffin reduced the respiratory activity about 50 per cent compared with the check lots and the other waxing treatments.

## DISCUSSION

Washing the turnips improved their appearance and reduced decay, presumably by removing decay-producing spores. Root trimming also improved the appearance of the turnips and did not increase decay or shriveling. These practices therefore, should be very desirable.

Waxing the turnips with wax emulsions, even with fairly high

concentrations of wax, did not affect the appearance of the roots or reduce their loss in weight. However the turnips were held under conditions of fairly high humidity, and practically no shriveling occurred even in the check lots.

Dipping the turnips in hot melted paraffin (96 per cent paraffin and 4 per cent resin) produced a relatively thick coating and gave the turnips a smooth, glossy appearance. This treatment very greatly reduced weight loss. It was also of benefit in that it reduced sprouting of new leaves and prevented initiation of new roots. The thick paraffin coating retarded gaseous exchange so that the  $\text{CO}_2$  evolved and  $\text{O}_2$  consumed were greatly reduced. This would result in a high  $\text{CO}_2$  and low  $\text{O}_2$  content in the internal atmosphere. In some products this partially anaerobic conditions causes breakdown and off flavors. In the case of turnips this condition apparently was not detrimental as no off flavors were detected, and it may have been beneficial as there appeared to be some reduction in internal breakdown.

Truscott and Thomson (3) give detailed direction for the use of hot paraffin. They suggest that the paraffin should be diluted with 2 to 5 per cent of resin, mineral oil, vaseline, or beeswax to make it less brittle. They emphasize that the turnips must be thoroughly dried of surface water before dipping so as to prevent burning and discoloration. With the wax at such a high temperature (250 to 270 degrees F) the exposure or dip must be very short (1 second).

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## Developmental Reversal of Dominance in *Cucurbita pepo*<sup>1</sup>

By OVED SHIFRIS, *W. Atlee Burpee Company,*  
*Doylestown, Pa.*

IN breeding crop plants we are too often inclined to conceive characters as static end-product manifestations rather than as dynamic or developmental expressions of the organism. Furthermore, some of our difficulties or failures in breeding may be due occasionally to a lack of proper appreciation, or lack of knowledge, of certain developmental and physiological processes which bring about the expression of these end-product characters.

The present paper presents a simple study of the inheritance of certain plant characters as developmental reactions. This study led not only to a better understanding of the genetical mechanism involved but also brought to light a new tool in plant breeding for the differentiation of genotypes on the basis of a developmental description of phenotypes.

A few years ago the writer found that some intervarietal crosses in *Cucurbita pepo* L. manifest a complete reversal of genetical ratios ( $F_2$ ) during development. Data on the inheritance of fruit color and growth habit have already been accumulated to permit a general discussion of the results and their practical and theoretical implications.

### MATERIALS AND METHODS

Table Queen (Syn. De Moine, Acorn) is a horticultural variety placed among the winter squashes but botanically classified with the pumpkins of *Cucurbita pepo* L. The seed is usually sown in the spring and fruits are harvested in the fall when fully ripe. Some of the outstanding features of this variety are the acorn shape and the persistent green color of the fruit, the high quality of the flesh, and the vine habit of growth. About 30 days usually elapse from the time of pollination to seed maturity and about 50 to 60 days until the fruit is fully ripe. Tapley *et al* (17) have given a detailed description of this variety.

A plant was found in the standard variety which had bush habit and persistent yellow fruit. In using the word "persistent" reference is made to the external color expression from the time of anthesis until the fruit is fully ripe, regardless of changes in color intensity during development.

The homozygous yellow-fruited "bush" strain was crossed with the standard green-fruited vine variety and the parents together with  $F_1$ , backcrosses,  $F_2$ , and some  $F_3$  and  $F_4$  progenies were grown and studied on the experimental grounds of the W. Atlee Burpee Company, Fordhook Farms, Doylestown, Pennsylvania from 1942 to 1945.

About 700 plants of one  $F_2$  population were marked and num-

<sup>1</sup>The writer wishes to thank Professor Edmund W. Sinnott, Director Scientific School of Yale University, Professor R. A. Emerson of Cornell University, and Mr. Francis Haxo of California Institute of Technology for reading the manuscript and for their valuable suggestions.

bered consecutively by placing a garden label near the stem base of each seedling 10 days after emergence. Records on growth habit and fruit color were taken at frequent intervals and complete history of each individual, in regard to these characters, was obtained.

In addition to the above cross, which was the main subject of the investigation, numerous intervarietal crosses involving fruit color types were made in 1942 but studies of this material were not carried out, in most cases, beyond the  $F_1$  generation. The Dictionary of Color by Maerz and Paul (10), henceforth mentioned as M & P, and the Horticultural Colour Chart issued by the British Colour Council in collaboration with the Royal Horticultural Society (1), henceforth designated as BCC, were used as standards for color comparison. The Dictionary proved more useful than the chart for the classification of the green-fruited lines and the Chart was more satisfactory for the classification of the yellow-fruited lines.

### DISCUSSION OF RESULTS

If one grows the  $F_1$  and the  $F_2$  of the cross yellow-fruited bush by green-fruited vine, Table Queen, and makes the classification *in the fall*, one finds that the  $F_1$  is yellow and that the  $F_2$  segregates in a ratio of 3 yellow to 1 green. On the basis of this analysis as well as on the analysis of the  $F_3$  and  $F_4$  one comes to a conclusion that fruit color is controlled by a single gene and that *yellow is dominant over green*. However, if classification is made *early in the season*, at time of anthesis or a few days later, one finds that the ovaries of the  $F_1$  are green and the  $F_2$  segregates in a ratio of 3 green to 1 yellow. One then concludes that *green is dominant over yellow*.

The inheritance of growth habit follows a similar pattern. Records taken relatively early in the season suggest a ratio of 3 bush to 1 vine and those taken later in the season give a ratio of 3 vine to 1 bush. Data may appear most confusing if taken in the mid-summer during the most active period of plant growth. One may conclude then that no "good" genetical ratios can be obtained and that the inheritance of fruit color and especially that of growth habit is rather complex and is probably controlled by many genes.

In tackling this problem, the writer has chosen two distinct phases of fruit development for the classification of color phenotypes:

1. *The Flowering Stage*, at time of anthesis of any pistillate flowers; this is a definite as well as convenient stage from the standpoint of color expression and classification.

2. *The Ripe Fruit Stage*, 50 to 60 days after anthesis or later. This is also a fairly definite stage, when color intensity seems to have reached its maximum expression and no visible color changes are noted thereafter.

The classification of growth habit, although a more difficult task, was also based on two developmental phases:

1. *Early Stage*, during the anthesis of the first few pistillate flowers.

2. *Late Stage*, when a plant reaches its maximum vegetative growth or thereafter.

The data presented in Tables I, II, and III indicate that the char-

TABLE I—INHERITANCE OF FRUIT COLOR (GREEN VS. YELLOW)  
IN *Cucurbita Pepo* L. VAR. TABLE QUEEN

Breeding Material	Size of Population (Plants)	Flowering Stage (Anthesis)		Ripe Fruit Stage	
		Green	Yellow	Green	Yellow
Green fruited parent.....	Large	+		+	
Yellow fruited parent.....	Large		+		+
F <sub>1</sub> .....	52	52			52
F <sub>1</sub> Observed.....		3229	1120	1042	3253
F <sub>1</sub> Calculated (3 : 1).....	4349 (Initial)	3261.75	1087.25	1073.72	3231.25
Total (for each stage).....		4349		4295*	
Standard error.....		28.52**		28.38**	

\*Apparently fifty-four plants were lost or otherwise unaccounted for.

\*\*Deviation insignificant.

acters of fruit color and growth habit of the two parental varieties are differentiated by two pairs of independent genes. The color expression, for example, is controlled by the same gene throughout fruit development. The same is true for the character of growth habit which is controlled by the other independent gene.

In the case of color inheritance it is interesting to note that when the F<sub>1</sub> is backcrossed to either parent the ratio is always 1 green to 1 yellow. The significant difference between the two backcrosses is the stage at which the segregation is observed (Table II). The F<sub>2</sub> data in Table III show clearly the course of developmental reversal of the genetical ratio based on individual plant history.

TABLE II—INHERITANCE OF FRUIT COLOR (GREEN VS. YELLOW) IN *Cucurbita Pepo* L. TABLE QUEEN (CLASSIFICATION OF BACKCROSS POPULATIONS)

Backcrosses	Flowering Stage (Anthesis)		Ripe Fruit Stage	
	Green	Yellow	Green	Yellow
F <sub>1</sub> X green.....	52	0	24	25
Total plants.....	52		49*	
F <sub>1</sub> X yellow.....	32	35	0	58
Total plants.....	67		58*	

\*Some plants were lost during the season.

Thus, a method is available for the isolation of any genotype—homozygous or heterozygote—in the F<sub>2</sub> or in the backcross populations. Persistent color types, in this particular cross, are always homozygous and all plants bearing green young fruits which later on become yellow are heterozygous and segregate in the following generation. This method enabled us to isolate, in the F<sub>2</sub>, or in one season, homozygous lines which combine the bush habit and persistent green color of fruit. Without the above information it would have taken us at least three additional seasons of testing in order to be sure that we possess a homozygous line combining these desirable characteristics. Therefore, it can be readily seen that a better understanding of character expression is not only of theoretical interest but may also lead to an immediate practical application.

TABLE III—INHERITANCE OF FRUIT COLOR (GREEN VS. YELLOW) AND GROWTH HABIT (BUSH VS. VINE) IN *Cucurbita Pepo* L. VAR. TABLE QUEEN. RECORDS WERE TAKEN ON THE EXPRESSION OF EACH F<sub>2</sub> SEGREGANT, DURING DEVELOPMENT. THESE RECORDS OFFERED THE OPPORTUNITY OF DETECTING THE GENOTYPE OF EACH PHENOTYPE AS WELL AS OF TRACING THE COURSE OF DEVELOPMENTAL CHANGES WHICH ARE THE CAUSE OF REVERSAL IN THE GENETICAL RATIO

Flowering Stage (Anthesis) - Early.			The Course of Developmental Changes of phenotypes Calculated figures in parenthesis.	Ripe Fruit Stage - Late.	
Phenotypes	Observed Numbers	Calculated Numbers (9:3:3:1)		Observed Numbers	Calculated Numbers (1:3:3:9)
Bush Green	318	321.75		41	35.75
Bush Yellow	101	107.25		106	107.25
Vine Green	117	107.25		96	107.25
Vine Yellow	36	35.75		329	321.75
TOTAL:	572*		572	572	
Chi Square	0.20**		5.44**	2.13**	

\*The original number of F<sub>2</sub> seedlings was 698. Not all of the missing 116 plants were lost from disease, some hills were not thinned properly, resulting in poorly developed plants which either perished away or never reached maturity. Also a section of the planting was made on a very poor soil; records from this section were not complete and therefore excluded from this table.

\*\*Deviations insignificant.

A color description of the two homozygotes and the heterozygote is given in Fig. 1. The green-fruited race changes from Parrot Green 21L6 (M & P) to a dark green color designated as 24A7 (M & P); the yellow-fruited race changes from Uranium Green 6 3/1 (BCC) to Orpiment Orange 10 (BCC) and the heterozygote changes from Parrot Green to Orpiment Orange during fruit development.

It is apparent that the switching mechanism which is responsible for the reversal in the genetical ratio is due to the developmental re-  
action of the heterozygote. Broadly speaking, this heterozygote manifests the characteristics of one parent at early developmental stages and the characteristics of the other parent in later stages of development.

Numerous observed crosses between yellow and green-fruited varieties suggest that the phenomenon of reversal of dominance is quite common in *Cucurbita pepo* L. The reversal reaction, however, may not follow the same course in all crosses. Three typical cases of heterozygote reversal of dominance are presented diagrammatically in Fig. 3. These three heterozygote reactions differ from each other in the time at which green is changed into yellow. The turning point in the first heterozygote (green-fruited vine by yellow-fruited bush, Table Queen) occurs early in the development of the fruit or about a week or so after anthesis; the turning point in a related cross occurs about 2 weeks after anthesis and in the third heterozygote after the fruit has reached maximum size, 25 to 30 days after anthesis.

Heterozygotes may differ also in another respect. In some hybrids the change from green to yellow is rather abrupt. (Fig. 1) whereas

Material	Fruit size Equatorial Diameter (in 1/16 inch)	Color Classification	
		Green - M & P	Yellow B. C. C.
Green-Fruited Strain	5	21L6 Parrot Green	
	10 (anthesis)	21L6 Parrot Green	
	20	21K4 Rainett Green	
	50	20L5 Absinth Green	
	60 (mature)	24A11 Mountain Gr. Forrest	
	Sixty days after anthesis	24A12 Brunswick Gr. Deep 24A7	
Yellow-Fruited Strain	5		63/1 Uranium Green
	10 (anthesis)		1/2 Sulfur Yellow
	20		603/1 Empire Yellow
	50		6/2 Indian Yellow
	60 (mature)		7/2 Saffron Yellow
	Sixty days after anthesis		8 Cadmium Orange 10 Orpiment Orange
F <sub>1</sub> Hybrid	5	21L6 Parrot Green	
	10 (anthesis)	21L5 Grass Green	
	20	20L3 Certosa	
	50		603/1 Empire Yellow
	60 (mature)		7/2 Saffron Yellow
	Sixty days after anthesis		8 Cadmium Orange 10 Orpiment Orange

FIG. 1. Relationship between size and color changes of fruit of two strains of Table Queen, *Cucurbita Pepo* L., and their F<sub>1</sub> hybrid, during development.

in others, such as in the cross Fordhook Zucchini by Connecticut Straightneck, the change is very gradual and may take place throughout a long period of fruit growth. Thus, the latter heterozygote goes through color changes from green to yellow as follows: (a) 18L7 (M & P); (b) Love Bird 18L6 (M & P); (c) 18L3 (M & P); (d) Citronelle 18L2 (M & P); (e) Chinese yellow 606 (BCC); (f) Saffron yellow 7 (BCC); (g) Cadmium Orange 8 (BCC); and finally (h) Tangerine Orange 9 (BCC). During the same period of fruit development the yellow-fruited race changes from (a) Grapefruit 19L1 (M & P), (b) Saffron yellow 7 (BCC), (c) Cadmium Orange, and (d) Tangerine Orange 9 (BCC). The green-fruited race, Fordhook Zucchini, starts from green and becomes darker until it is "black" green in color or 24A5 (M & P). It should be emphasized that the green color of this heterozygote does not disappear completely until the fruit is fully mature. In some crosses between certain green and yellow races the change from green to yellow is never complete and some green areas are present even on the ripe fruit.

The inheritance of the two characters reported here is unusually clear (fruit color and growth habit). It indicates that a simple Mendelian phenomenon may be interpreted erroneously or incompletely if characters are regarded as *static* rather than *dynamic* manifestations. Indeed, the data become meaningful only when the characters are viewed as developmental processes.

A few examples of reversal of dominance were reported by Goldschmidt (4), Honing (5) and Ferwerda (3).

Honing crossed two races of tobacco, normal (*deli*) by *deformis*. The F<sub>1</sub> is first normal but becomes like *deformis* later on. In crossing

F<sub>1</sub> with normal he obtained 549 normal individuals and 541 plants which behaved like F<sub>1</sub> (see also Table II of this paper). In crossing the F<sub>1</sub> with *deformis* he obtained 590 plants like *deformis* and 586 like F<sub>1</sub>.

Goldschmidt crossed two races of *Lymantria dispar*, one with transparent cuticle (bright yellow epidermal markings) and the other with dark cuticle (epidermal markings visible only at the very early stages). The young F<sub>1</sub> caterpillar is light but later on in development becomes darker until finally it is entirely pigmented.

A similar case of "dominanzwechsel" was reported by Ferwerda. He crossed an orange race of *Tenebrio molitor* (a meal worm) with a brown race. The larva and pupa of the F<sub>1</sub> are orange but the imago is brown.

Both Goldschmidt and Ferwerda interpreted the phenomenon of change in dominance in terms of rate or velocity of pigment accumulation. Thus, Goldschmidt assumed that the rate of pigment production in the dark race of *Lymantria* is so high that even the young organism is already pigmented, whereas in the light race the rate of pigment formation is so low that it does not produce any visible effect. The heterozygote, on the other hand, produces an intermediate rate and therefore the young light caterpillar becomes dark only in later stages of development when sufficient pigment is accumulated to make it visible. Goldschmidt's interpretation, with some modifications, may apply to the cases reported here on reversal of dominance in *Cucurbita pepo* L.

#### THE GENETICS OF FRUIT COLOR IN CUCURBITA PEPO L.

In the course of breeding and genetical studies in *Cucurbita pepo* L. an attempt was made to classify varieties on the basis of their fruit color reactions. Such a classification does not have any horticultural value but may serve as a basis for future genetical and biochemical investigations in this species. All the horticultural varieties and strains of *Cucurbita pepo* L. can be divided into at least six major color groups as follows:

- I. *White*:—White Bush Scallop, Wood's Prolific, certain strains of English Vegetable Marrow, and some gourd varieties. At anthesis the ovary is usually green. The turning point from green to white is abrupt and occurs a few days later.
- II. *Cream*:—Certain strains of the Patty Pan group, Burpee Fordhook (Vine and bush strains), Perfect Gem, etc. The ovary at anthesis is usually green. The turning point from green to cream is abrupt and occurs at early stages of fruit development.
- III. *Yellow*:—Early Prolific, Golden Summer Straightneck, Golden Summer Crookneck, Giant Summer Straightneck, Giant Summer Crookneck, Yellow Bush Scallop, Golden Table Queen Bush, and so on. The ovary at anthesis is either green or yellow. If green it disappears within a few days. The turning point is abrupt and occurs at early stages of fruit develop-



ment. The ripe fruit may be Cadmium Orange (8 BCC), Tangerine Orange (9 BCC), or Orpiment Orange (10 BCC).

- IV. *Green-Yellow*:—Connecticut Field (Big Tom), Small Sugar (New England Pie), Golden Oblong, and perhaps Winter Luxury. The ovary at anthesis is always green. The green color is of distinct pattern and persists until the fruit has almost reached its maximum size. The turning point is relatively slow and occurs *very late* in fruit development. The ripe fruit is Persimon Orange 710 BCC or Persimon Orange 710/2 BCC.
- V. *Green*:—This group consists of a number of green, black green, and gray fruited varieties and strains which vary in color intensity and pattern. Strains of Black and Gray Zucchini, Burpee Fordhook Zucchini, and various strains of Table Queen belong to this group. A few orange-colored areas may be seen on some ripe-fruits or during winter storage. Orange areas may also occupy parts of the fruit that face the ground.
- VI. *Striped or Mottled*:—Long Green Trailing, Mandan, Delicata, Sandwich Island, Cocozelle, Top of the Market, and various other strains of Italian and English Vegetable Marrow. Fruits are white or light green blotched with small, irregularly laced dark green areas or with alternating dark green stripes. If background is light green it turns yellow when fruit is ripe.

In spite of such remarkable diversity of fruit color types and their interesting developmental reactions, in this species, very little has been published on the genetical mechanism and practically nothing is known about the nature and biogenesis of the pigments involved.

Sinnott and Durham (15) made the first genetical study on the inheritance of fruit color in *Cucurbita pepo* L. They concluded that the fruit color types are differentiated by at least three independent genes  $W_1-w_1$ ,  $W_2-w_2$ , and  $Y-y$ . Yellow (Y) is dominant over green (y), in presence of the two genes  $w_1$  and  $w_2$ , and white ( $W_1$  and  $W_2$ ) is epistatic to yellow. Preliminary tests suggest that the pigment production of groups II (cream), III (yellow), IV (green-yellow), and V (green) may be controlled by a series of major allelomorphs designated tentatively as  $Pc^{(n)}$ ,  $Pv^{(n)}$ ,  $Psv^{(n)}$ , and  $P\bar{s}^{(n)}$  respectively. Altogether there may be at least 14 alleles. Fig. 2 represents a diagrammatic description of the developmental responses of the major color genotypes. Each P allele is associated with a given developmental reaction and specific color intensity (n) of the ripe fruit. Thus,  $Pv^1$  stands for a yellow color reaction the final color of which is Cadmium Orange (8 BCC) and  $Pv^5$ , for example, stands for the reaction of the yellow-fruited line, such as was used extensively in the present investigation, the final color of which is Orpiment Orange (10 BCC). The  $P\bar{s}^1$  allele stands for a reaction which is green throughout a long period of time and then becomes yellow, the final color of which is Persimon Orange (710 BCC). The  $P\bar{s}^1$ ,  $P\bar{s}^2$ ,  $P\bar{s}^3$  — series represents

Color Groups	Developmental Color Reaction From Anthesis to Ripe Fruit	
	Ovary	Ripe Fruit
I.- White W <sub>1</sub> & W <sub>2</sub>	Green	White
II.- Cream P <sup>o</sup> (n)	Green	Cream (including Chrome Yellow 605/1 BCC.)
III.- Yellow pY(n)	Green	Cadmium Orange (8 BCC)
	Yellow	
	Green	Tangerine Orange (9 BCC)
	Yellow	Orpiment Orange (10 BCC)
IV.- Green Yellow pGY(n)	Green	(710 BCC) Persimmon Orange
	Green	(710/2 BCC)
V.- Green pG(n)	Green	"Black" and "Gray" (4-6 Strains)

White

Cream

Yellow

Green

Turning Point

\* After Sinnott and Durham (1922)

FIG. 2. Diagrammatic presentation of the developmental reaction of major fruit color groups in *Cucurbita Pepo* L.

persistent green color reactions which may differ from each other in various ways such as in chlorophyll concentration, a change in the ratio between chlorophyll a and b, the presence of chlorophyll breakdown products, or, perhaps, to a pigmentation of another sort. It is also probable that the color of some green and yellow-fruited lines, which have not yet been studied, may be controlled by independent genes.

The inheritance of the striped-color types of group VI is not known but the heterozygotes which the writer produced by crossing striped and non-striped strains were always striped. One heterozygote of a cross between a white "gourd" and an orange-fruited pumpkin (Big Tom) produces fruit which is white until it reaches its maximum size and then turns cream, suggesting that the epistasis of some W genes may not be always complete. It is also significant that some homozygotes in group III (see Fig. 2), for example, exhibit a developmental change in fruit color similar to that of the heterozygote described in Fig. 1. Therefore, one can state categorically that the "reversal" phenomenon in itself is fundamentally a manifestation of gene action and not necessarily a peculiar behavior of the heterozygote. One can hardly utilize this phenomenon in his breeding operations without a full appreciation of the latter statement. Indeed, whenever a reversal of dominance can be demonstrated one should not expect to identify heterozygotes on the basis of their developmental responses alone but

rather as they are compared with the responses of the corresponding parental homozygotes.

The nature of "dominance" in respect to the inheritance of fruit color requires further elucidation. From a standpoint of end-product manifestation one may be justified in saying that, in many cases, yellow is completely dominant over green. However, evidence from several intervarietal crosses indicates that the green color reaction is not merely a residual heredity. It has already been indicated (Fig. 3)

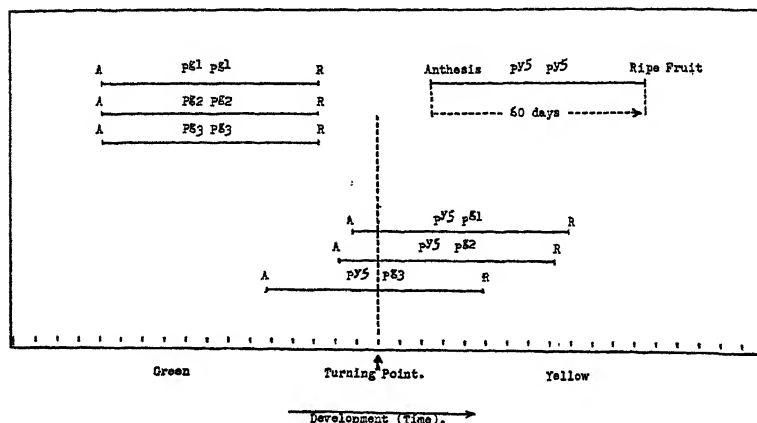


FIG. 3. Graphic presentation of color development in three heterozygotes of crosses between a yellow fruited strain  $Py^{6y6}$  (right), and three green-fruited strains  $Pg^1\ Pg^1$ ,  $Pg^2\ Pg^2$ , and  $Pg^3\ Pg^3$  (left). Each horizontal line represents the length of time from anthesis to ripe fruit stage, during which time changes in color occur. The perpendicular line indicates the relative position of the turning point in each heterozygote.

that different heterozygotes give distinctly different responses in regard to *stage* and *speed* of conversion from green to yellow color. Since the production of these heterozygotes involves the same yellow-fruited parent it is logical to assume that at least some alleles for green color have a positive effect. The terms "dominance" and "recessiveness" are not especially helpful nor is the designation of alternate alleles by capital and lower-case letters. What really matters is the chain-reactions which each allele controls during fruit development.

There are numerous reports of complete dominance in studies of color inheritance. Lawrence and Price (8) state that in case of anthocyanin color, in flowers, "the presence or absence of anthocyanin is here determined by a single gene, which in the recessive condition is apparently inactive". The same authors show also that in *other* plant species the "absence" of pigment is dominant over the "presence" of pigment. Even in cases of complete dominance and *apparent* static relationship, such as "absence" and "presence" of something, the genic reaction can be described in more dynamic terms. It has been assumed, for example, that the red color (RY) of a tomato

fruit is due to the "colored" epidermal layer and the pink color (Ry) to the "colorless" condition. LeRosen, Went, and Zechmeister (9) have demonstrated, however, that the dominant Y gene controls a reaction which produces a tenfold increase in an alkali soluble yellow pigment, in the thick cell walls of the epidermis, as compared with the reaction produced by the recessive y allele. The transparent skin was actually found to contain this pigment but the quantity is not large enough to become visible.

The available data (8) on genic control of the biogenesis of anthocyanins and anthoxanthins in flowers, give us a more illuminating interpretation of color inheritance than has been formerly presented. The anthocyanin color variations are differentiated by single genes which control, for example, the number of substituent hydroxyl groups in the anthocyanidin molecule, the methylation of the hydroxyl groups or the position of the attachment of sugar molecules. A higher state of oxidation is usually dominant over a lower one; thus, the dephinidin pigment types are dominant over cyanidin, and the cyanidin pigment types are dominant to pelargonidin. Gene interaction plays an important role in the differentiation of the anthocyanins and anthoxanthins which are similar in structure. These substances are assumed to be formed from the same precursor which is present in limited quantities. There is apparent competition between the two and if most of the precursor is utilized in the synthesis of one pigment, then, of necessity, less of the other is produced.

Zechmeister, Beres and Ujhelyi (21, 22) found that the mature corolla of *Cucurbita pepo* L. contains considerably more Kryptoxanthin ( $C_{40}H_{56}$ ), and tenfold increase in zeaxanthin ( $C_{40}H_{56}O_2$ ) than the corolla of the young buds. The remarkable increase in zeaxanthin during flower development is usually associated with a similar decrease in lutein (xanthophyll). Moreover, the mature flower is distinguished also by the presence of a newly isolated pigment which these investigators named petaloxanthin ( $C_{40}H_{56}O_3$ ). It is also interesting to mention here the work of Kuhn and Wiegand, 1929 (after Schopfer, 13), on *Physalis Alkekengi*. At early stages the calyx contains chlorophyll, lutein, and carotene but as it turns yellow, the carotene increases and xanthophylls decrease. At maturity chlorophyll is absent, physalin (dipalmitic ester of zeaxanthin) abundant and the free xanthophylls which remain are represented particularly by zeaxanthin. Both fruit and calyx are then red.

Unfortunately, no studies are available on the relationship between genes and the biogenesis of chlorophylls and carotinoids in the pumpkin fruit. It is generally known, however, that carotinoid pigments are present in chromoplasts, the latter being formed either from leucoplasts or chromoplasts following chlorophyll decomposition. Schopfer (13) reports that phytol is believed to be the precursor of both chlorophylls and carotinoids, part of it being used in the formation of each of these groups of pigments. It is also assumed that the production of phytol continues throughout plant life and thus a reserve of phytol is provided for the rapid formation of carotene during the ripening period of the fruit.

It is impossible to assign the various P alleles certain reactions in the absence of biochemical data. However, a number of interpretations can be offered.

All young ovaries of *Cucurbita pepo* L., regardless of fruit color classification, are green at early bud stage and contain chlorophylls and carotinoids. If it is true that these pigments have a common precursor (phytol), the role of P gene would then be to determine, directly or indirectly, whether the reserves of such precursor would be used primarily for the accumulation of chlorophylls or solely for the accumulation of carotenoids. Thus, it may be assumed that the main function of  $P^{g(n)}$  allele is to provide favorable conditions for the accumulation of chlorophylls whereas the major role of  $P^{y(n)}$  allele would be to block the chlorophyll side chain thus diverting the isoprenoid residues or phytol reserves to the carotinoid branch exclusively. A simpler interpretation would be to assume that the speed of conversion from green to yellow depends on the level of oxidation of chlorophylls. Thus, certain heterozygotes, of crosses between green and yellow-fruited strains, produce a lower level of oxidation than the yellow homozygotes and therefore the change in color occurs only in later stages of development. Whatever the true interpretation may be one must realize, on the basis of available knowledge, that the role of gene P is to initiate a sequence of reactions which have to do with pigment transformation, accumulation, depletion, as well as to the possible production of new pigments, as pointed out by Zechmeister *et al* (22).

#### THE GENETICAL CONTROL OF GROWTH HABIT IN *CUCURBITA PEPO* L.

Although the genetical mechanism controlling growth habit is similar to that of fruit color it represents some problems which deserve special consideration.

The vine habit of growth is expressed, at early stages, in a single, trailing, relatively long stem of long internodes. At later stages, the main stem increases in length and long side branches with lengthened internodes appear.

The "bush" type, such as was used widely in this investigation, is expressed, at early stages, in a single, upright, relatively short stem of shortened internodes. At later stages, two or three short stems may develop. This "bush" line is quite prolific and appears normal in every respect. In some varieties of *Cucurbita pepo* L., tree-like inbreds can be isolated which may be regarded more typical bush in habit, having no side-branches. These inbreds do not seem to trail much even at late stages of plant growth. All the bush types can be classified, however, as "dwarfs" since their common characteristic is shortened internodes.

At early stages, or at time of fruit set, the heterozygote of the cross between the vine and bush forms resembles the homozygous bush but as it grows the internodes become longer until, at the end of the season, it is almost indistinguishable from the vine variety. However, the reversal is not entirely complete.

On the basis of developmental analysis, the character of growth habit has been shown (Table III) to be differentiated by a single pair of alleles.

The more common approach of static genetics to character analysis is ineffective, in this case, since the segregation in the  $F_2$  population, during the active period of growth, suggests quantitative rather than qualitative inheritance. This confusion is also due to the fact, not too often realized, that *characters of some heterozygotes are more subject to changes during development and are more susceptible to environmental variations than the comparable characters of the homozygotes*. This is especially true when we are dealing with physiological processes associated with growth and development.

The cause of reversal of dominance in the heterozygote Table Queen vine by Table Queen bush can be expressed hypothetically in terms of genes and availability of auxin. It is generally assumed that auxin is responsible for stem elongation. Van Overbeek (11) demonstrated that the dwarf type of growth of nana corn as compared with normal corn is associated with higher destruction of auxin in the mesocotyl tip. The higher destruction of auxin may be due to a change in oxidation levels since the nana strain shows also a higher catalase and peroxidase activity. The pumpkin heterozygote (bush by vine) could produce an intermediate rate of reaction and therefore the elongation of internodes does not occur until sufficient quantity of auxin is accumulated. Apparently, the elongation of internodes, in the heterozygote, depends on a delicate physiological balance and it is suspected that microecological variations can modify this balance. As a result of such internal and external influences the heterozygotes in the  $F_2$  generation do not represent a distinct class but rather a continuous series of variations, between the typical bush and the typical vine forms, being part of the bush class at early stages and then gradually absorbed in the vine group at later stages of growth.

The difficulty in analyzing the genetical control of certain so-called quantitative characters may be due to the following:

1. To a large number of genes.
2. To the different roles which different genes may play during development.
3. To the different responses of different genotypes to environmental variations.
4. To various types of allelic relationships.

It is sometimes difficult to draw the line between "qualitative" and "quantitative" characters but the writer has demonstrated that even a character which is differentiated by a single gene may seem to the observer as quantitative and due to many genes. In tackling the problem of genetical control in such cases a developmental approach to character expression may help considerably in the analysis.

Shifriss *et al* (14) have shown, for example, that the inheritance of resistance to mosaic-virus in *Cucumis sativus* L. is extremely complicated when the data are analyzed in the ordinary way. However, when the segregating populations are analyzed first at cotyledon stage, be-

fore gross differentiation has taken place, definite genetical data can be secured, indicating the role of three basic genes. It is very difficult to analyze the developmental mechanism of resistance to the mosaic-virus, in cucumbers, because of the prominent role which the environment plays in its effect on the virulence of the virus, and the possible great number of genes or gene modifiers which exert their influence during development. In this connection it is interesting to remark that the  $F_1$ , Symptomless by Susceptible, is symptomless at cotyledon stage but may show signs of infection on the first true leaf or at later stages.

It has been shown, in the above discussion on the genetics of fruit color and growth habit, that the heterozygotes for these two characters manifest the phenomenon of developmental reversal of "dominance". In either case the assumption is that the heterozygotes produce an intermediate *rate* of reaction which in time brings about this reversal. Such allelic relationship may also be viewed as a race between two opposing reactions during development. The time at which this reversal occurs as well as its duration depend upon the potency or the dose of each of the opposing factors involved. From the standpoint of character expression, neither allele is truly dominant, both having their effect upon development.

The phenomenon of reversal of dominance may be more common than has been heretofore realized. Its possible implication to the general problem of gene action and more specifically to the phenomenon of heterosis is discussed in the following section.

#### HETEROZYGOSITY AND HYBRID VIGOR (THEORETICAL)

The study of the heterozygote has been and still is a promising field of investigation of gene action. The broad phenomenon of heterosis, for example, has to be explained by a manner in which genes act in the heterozygous condition. Since the publication of Keeble and Pellow's theory (7) of interaction of dominant factors and the "Dominance of Linked Gene Hypothesis" by Jones (6) there has been considerable emphasis placed on dominance as static manifestation of end products.

East (2) suggested that hybrid vigor is due to a cumulative effect of alleles each of which may produce a slightly different physiological process. Stadler (16) suggested a manner by which two alleles can produce heterotic effect. In maize each of the eight reported alleles of the R series controls the color production in many different regions of the plant. The differences in reaction between alleles are due not only to differences in color expression or intensity in a given region, but also to differences in regions affected. A so-called "dominant" allele in one region may be "recessive" to the same alternate allele in other region. The effect of R in different regions can be represented tentatively by different letters and the phenotypic expression in any given region by capital or lower-case letters. If R were a gene controlling some substance important in cell metabolism, heterozygotes such as R (ABcdEf) /  $R^1$  (aBcDeF) would be expected to manifest heterosis.

The phenomenon of developmental reversal of dominance led the writer to the hypothesis that heterotic effect could be produced by alleles acting differently at different stages of growth. Such a type of heterosis would be expressed, of necessity, in terms of *total* plant performance during development rather than in terms of any given stage.

It may be fitting to mention here the case of hybrid vigor in the tomato. Powers (12) demonstrated that the interaction of favorable dominant genes is not an essential part of a comprehensive theory of heterosis. He showed that, in the tomato, low number of fruits and small size may manifest partial dominance but the product of these two components is higher in the hybrid than in the higher yielding parent. Powers' data apply to some crosses between very small and large-fruited varieties. However, genes for fruit size may not have such a significance in other crosses. The writer found that the highest yielding hybrids of crosses among the commercial large-fruited varieties are distinguished primarily by their phenomenal increase in number of fruits. Moreover, these hybrids often produce smaller fruits than the smaller-fruited parent. Our data, based upon numerous crosses among the leading American varieties, indicate that the average fruit size of the hybrids may be intermediate (closer to the geometric or arithmetic means), larger than the large-fruited parent or smaller than the smaller-fruited parent depending on *combination* and *seasonal* variations. The writer wishes to emphasize that limited genetical studies of certain end-product characters, without regard to plant development as a whole, cannot possibly elucidate the problem of hybrid vigor which is fundamentally a physiological manifestation. The increase in yield, expressed either as interaction of genes for size and number of fruit or in production of numerous fruits, is closely associated with increase in plant size, a long bearing season, and in the ability of flowers to set even under adverse weather conditions, to mention only a few outstanding features.

Whaley (18, 19) concluded that in the tomato determinate organs of the hybrids increase in number but not in size and that *heterosis is the result of more rapid growth of the hybrid during early stages, augmented by less rapid slackening of growth*. Our results seem to correspond with this general conclusion. Heterosis in crosses between very early and late varieties is expressed not necessarily in an increase of yield at any given picking, during the harvest season, but rather in the maintenance of a relatively fair level of production throughout a long period of time with the result of increase in *total* yield. Hybrid vigor, in these particular cases, should be attributed to a developmental cumulative reaction of the heterozygotes. One is tempted to interpret this type of heterosis on the basis of developmental reversal of dominance. Thus, one may say that the genes which make for early-high production in the early varieties manifest partial dominance in the hybrids during the early part of the harvesting period whereas the alleles from the late varieties express partial dominance later on. If, however, one interprets the developmental reversal of dominance in terms of *rate* or *velocity* then one has to assume that these hybrids produce an intermediate *rate* of reaction between the parental lines.



This type of intermediacy has apparently a peculiar advantage for the hybrid in that it creates a better balance between the vegetative and the reproductive phases of the plant, thus enabling it to bear longer or to use more efficiently the length of the growing season. Hybrids of crosses between very early and very late varieties should be expected to express their maximum heterosis in regions of a fairly long growing season or be inferior, in total yield, to early varieties, in regions of very short growing season. This is borne out by our results of hybrid testing on a nation-wide scale. It is not intended here to convey the impression that the above postulated theory of heterosis will apply to all crosses in the tomato (see Whaley and Long, 20) but rather to point out the possibility of a new manner by which allelic as well as gene interactions may bring about heterotic effects.

Should the above hypothesis stand the test of future investigations, this type of hybrid vigor may be described as *Developmental Heterosis*.

#### SUMMARY

A green-fruited line of vine habit was crossed with a yellow-fruited line of bush habit in *Cucurbita pepo* L. var. Table Queen. In the  $F_2$ , the genetical ratio is 9 green-bush:3 green-vine:3 yellow-bush:1 yellow vine early in the season, at *Flowering Stage*, and 1 green-bush:3 green vine:3 yellow-bush:9 yellow-vine late in the season, at the *Ripe Fruit Stage*. This reversal, in the genetical ratio, is due to the reaction of the heterozygotes which, broadly speaking, manifest the characteristics of one parent early in the season and the characteristics of the other parent later on. All homozygotes and heterozygotes can be isolated individually in the  $F_2$  generation on the basis of their developmental reactions.

Crosses between numerous green and yellow-fruited varieties of the said species indicate that heterozygotes differ from each other in *time* at which the turning point occurs as well as in its *duration* depending on the kind of alleles which make up the genotype. Although the change in fruit color is always from green to yellow and in growth habit from bush to vine the reversal may not always be complete.

The  $F_2$  of the cross "bush" by vine is of special interest because of its superficial resemblance to quantitative inheritance. This is due to the reversal of dominance and perhaps to the greater susceptibility of the particular heterozygote to environmental modifications.

The phenomenon of developmental reversal of dominance has not been sufficiently studied or appreciated, in the past, by geneticists and plant breeders who are absorbed largely in studies of end-product characters. It has been demonstrated that even a simple monogenic inheritance may be interpreted erroneously or incompletely if characters are viewed as *static* rather than *dynamic* manifestations. In any breeding operation it would seem advisable to study the developmental expression of the  $F_1$  heterozygote. Such a study may prove helpful, in and thus save years of work.

A new concept of *Developmental Heterosis* is suggested as due to

developmental reversal of dominance. This may be just one of the many ways by which gene and allelic interactions bring about heterotic effects.

some cases, if one attempts to isolate homozygotes in the  $F_2$  generation

*Cucurbita pepo* L. represents a very favorable material for the geneticist and the chemist of plant pigments for studies of gene action. This is true because of the diversity of fruit color types in this species, their simple inheritance, the interesting developmental reactions manifested, and the advantages of using fruits which furnish abundance of material for chemical analysis throughout development. Studies on the biosynthesis of fruit pigments in *Cucurbita pepo* L. may throw considerable light on the problem of gene action.

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## The Effect of Maturity and Storage on the Carotene Content of Carrot Varieties

By G. B. BROWN, *Cheyenne Horticultural Field Station,  
Cheyenne, Wyo.*

THIS study was undertaken to determine the importance of varietal differences in the carotene content of Wyoming-grown carrots and to determine the effect of winter storage upon their carotene content.

Barnes (3), Hansen (6), Magruder (11), Pepkowitz (14), and Werner (17) found that the carotene content of the carrot root increased up to approximately 100 days after planting, then remained fairly constant. Smith, Caldwell, and Burlinson (16), working in Arizona, found increases in the carotene content of Imperator and Chantenay varieties up to 200 days after planting.

Hansen (6) found Imperator slightly higher than other varieties tested. Pepkowitz (14) found Nantes higher in carotene 90 days after planting than Chantenay or Imperator. Kemmerer and Fraps (8), using dehydrated carrots, found Long Orange higher than Nantes, Imperator, or Chantenay. Bills and McDonald (4) found Scarlet Horn highest in carotene of the varieties tested, with Oxheart, Long Orange, Danvers Half Long, Chantenay, and Earliest Scarlet Forcing (French Forcing) following in the order given.

Results of workers in different localities vary greatly insofar as the carotene on a fresh weight basis in any one variety is concerned. Bills and McDonald (4), in Indiana, give a value of 8.0 milligrams per 100 grams for Chantenay. Barnes (3), in New York, shows a value of 30.6 mg/100 gm for Chantenay. Hansen (6) shows results varying from 6.75 to 9.91 mg/100 gm for the Chantenay variety grown in different localities in Oregon. Smith, Caldwell, and Burlinson (16) found values up to 20.6 mg/100 gm on 180-day-old Chantenay carrots grown in Arizona, while Pepkowitz *et al* (15) in Rhode Island show a mean value of 4.66 mg/100 gm for the same variety. Barnes (3) suggests that soil temperatures influence the carotene content to some extent, in that low temperatures cause a lighter color in the root. Emsweller, Burrell, and Borthwick (5) have shown that color and carotene content are proportional. Hansen (6) states that the rate of carotene accumulation in the roots decreases at low temperatures.

Workers in New Mexico (1) reported an increase in carotene when carrots are first stored, then a decrease. Werner (17) found no change in the carotene content of stored roots until sprouts started in the spring, when there was a slight decrease. MacLeod and Utley (10), using a bio-assay, found no increase in vitamin A in stored carrots. Barnes (3) found that carotene in carrots decreased in storage up to 80 days, then increased slightly. Langley, Richardson, and Andes (9) state that carotene did not decrease in storage.

### MATERIALS AND METHODS

*Experimental Design:*—Babb, Kraus, and Magruder (2) have classified the orange-fleshed carrot varieties into nine major groups, based

mainly on similarity of root characteristics. Varieties selected to represent these nine groups were as follows: Group 1, French Forcing; Group 2, Scarlet Horn; Group 3, Oxheart; Group 4, Chantenay; Group 5, Danvers; Group 6, Imperator; Group 7, James Intermediate; Group 8, Long Orange; and Group 9, Nantes. No attempt was made to compare these varieties with others in the same group, but each one chosen is typical of its particular group. These nine varieties were planted June 15, 1946, in randomized blocks, using four replications for each variety. The soil was a Cheyenne Loam, Heavy Phase, and was not fertilized. The entire planting was irrigated when necessary to maintain good growth. The plants were not thinned.

✓ The first samples for analysis were taken September 15, 90 days after planting, and others at intervals of approximately 2 weeks thereafter until the final sampling October 28. After the final sampling the remaining roots were harvested and stored in tubs of dry sand in a root cellar kept at 36 to 40 degrees F. Each tub contained the roots from a single plot, and the tubs were randomized in the same manner as the field planting. Two subsequent analyses were made on these stored roots at intervals of 1 month. While no published data are available on the subject, experience has shown that storing of carrots in dry sand in the root cellar is superior to other methods of storage at this station.

As most of the literature reports the carotene content of carrots on a fresh weight basis, dry weights were not determined on samples taken for carotene analyses at different stages of growth. However, it was believed that loss of moisture in storage would make advisable the reporting of carotene in stored roots on a dry weight basis.

*Sampling:*—To avoid the selection of only the largest roots, carrots from 2 lineal feet of row in each plot were taken, using all the roots present except those that were obviously off type for the variety. The roots, numbering 6 to 12, were taken to the laboratory, washed and dried. These were quartered lengthwise after removal of the crown and the quarters cut further when necessary to obtain a section of approximately the same weight from each carrot. These wedge-shaped portions were ground in a food chopper and thoroughly mixed. Investigation has shown that carotene is not destroyed through enzymatic action in the ground roots. A 20-gram sample was used for the analysis. The stored carrots were sampled in the same way, except that sections from 10 carrots were used, and a portion of the ground, mixed sample was taken for dry weight determinations.

*Chemical Methods:*—The method used is essentially the one described by Moore (12) and Moore and Ely (13), modified by using an alcoholic solution of potassium hydroxide to wash the petroleum ether solution before filtering through the adsorption column. It was found that the methanol-KOH solution removed some pigments that would pass through the column of dicalcium phosphate with the carotene and cause higher colorimeter readings than were justified by the amount of carotene present. As chlorophyll is not present in carrot roots (14), the ordinary procedures for separation of chlorophyll were omitted.

The light transmission of the extract was determined by the use of a Klett-Summerson colorimeter, using blue filter No. 42, and the carotene content was calculated by a previously determined factor. The factor was obtained by taking transmission readings on several known concentrations of pure carotene<sup>1</sup> in petroleum ether. Concentrations from 1 to 12 milligrams per liter gave the same factor. As the aliquots of the carrot extracts fell within this range, the use of the factor was justified.

Dry weight determinations were made by drying to constant weight in an electric oven at 95 degrees C.

As equipment was not available, no separation of the various components of carotene was made. Crude carotene is in general a good measure of vitamin A from a nutritional standpoint, and, according to Harper and Zscheile (7), carotenoid pigments other than alpha- and beta-carotene occur in very small amounts in the carrot root.

## RESULTS AND DISCUSSION

*Fresh Roots:* The data on the carotene content of the carrot roots at different stages of growth are shown in Table I. An analysis of

TABLE I—CAROTENE IN NINE CARROT VARIETIES AT FOUR STAGES OF GROWTH (MG/100 GM FRESH ROOT)

Days After Planting	90	105	120	135	Average (Variety Mean)
Variety	Mg	Mg	Mg	Mg	Mg
Scarlet Horn.....	4.13*	7.27	5.44	7.08	5.98
French Forcing.....	4.04	7.11	5.97	6.36	5.87
Nantes.....	4.09	6.05	4.69	5.72	5.14
Imperator.....	4.36	5.74	4.06	5.85	5.00
Chantenay.....	4.15	5.69	4.28	5.44	4.89
Danvers.....	3.77	5.61	4.08	5.78	4.81
Long Orange.....	2.90	4.29	3.40	4.28	3.72
Oxheart.....	2.48	4.57	3.34	4.36	3.69
James Intermediate.....	2.40	4.30	2.90	3.55	3.35
Average (Date Mean).....	3.62	5.63	4.24	5.38	—
Difference required for significance between variety means	1 per cent.....				0.78
	5 per cent.....				0.59
Difference required for significance between date means	1 per cent.....				0.52
	5 per cent.....				0.39

\*Averages for four replications.

variance showed that statistically significant differences exist between varieties, between periods of growth, and between replications. The interaction between periods of growth and replications is significant at the 5 per cent point. As the carotene is reported on a fresh weight basis, the interaction is of doubtful significance, as it could be attributed to differences in moisture content of the roots, as could also the significant differences found between replications.

The greatest difference in carotene content among the different periods of growth is between the 90-day period and the 105-day period. There is no significant difference in carotene content between the 105-day period and the 135-day period. The carotene content at the 120-

<sup>1</sup>Obtained from General Biochemicals, Inc., Chagrin Falls, Ohio.

day period is significantly lower than either the 105- or the 135-day period. This could be due to a heavy rain which fell two days before the 120-day period, probably increasing the water content of the roots. At the other dates of analysis the soil was fairly dry.

At 90 days, Imperator and Chantenay appear higher in carotene, although the difference is not statistically significant. Some varietal differences in carotene content are highly significant. Scarlet Horn and French Forcing are higher in carotene than any other varieties tested after the 90-day period of growth. Long Orange, Oxheart, and James Intermediate are lower at all periods of growth. At the 105-day period and at the final harvest at 135 days, Scarlet Horn and French Forcing are significantly higher than Nantes, Imperator, Chantenay, and Danvers—among which four varieties there is no significant difference.

*Stored Roots:*—One variety, James Intermediate, did not produce sufficient roots in all replications to be included in the analysis of variance. One replication of this variety showed 40.58 milligrams of carotene in 100 grams of root on a dry weight basis when placed in storage, 54.38 milligrams after 30 days, and 43.48 milligrams after 60 days.

All varieties increased in carotene on a fresh weight basis due to loss of moisture in storage. Figures on a fresh weight basis (Table II)

TABLE II—CAROTENE IN EIGHT CARROT VARIETIES DURING STORAGE  
(MG/100GM)

Storage Period (Days)	0		30		60		Average	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Variety	Mg	Mg	Mg	Mg	Mg	Mg	Mg	Mg
French Forcing.....	6.36*	61.31*	8.12	73.66	10.06	74.87	8.18	69.95
Scarlet Horn.....	7.08	72.29	7.83	71.47	9.09	79.58	8.00	74.45
Imperator.....	5.85	54.50	7.90	64.21	8.38	66.90	7.38	61.33
Nantes.....	5.72	55.56	6.98	67.15	7.11	63.13	6.61	61.95
Danvers.....	5.78	57.39	6.74	59.47	6.64	60.03	6.38	58.96
Chantenay.....	5.44	55.13	6.68	62.25	6.72	63.39	6.28	60.25
Oxheart.....	4.36	42.61	5.68	52.10	6.66	59.68	5.56	50.46
Long Orange.....	4.28	36.94	5.76	48.31	6.10	44.80	5.38	43.35
Average for storage period..	—	54.34	—	62.33	—	63.60	—	—
Difference required for significance between variety means (dry basis)	1 per cent.....						9.00	
	5 per cent.....						6.74	
Difference required for significance between period means (dry basis)	1 per cent.....						5.51	
	5 per cent.....						4.12	

\*Average of four replications.

are merely for comparison with Table I. Conclusions regarding change in the amount of carotene in the stored carrots are from the figures calculated on a dry weight basis. An analysis of variance showed statistically significant differences existing between varieties and between dates of analysis (storage periods). The means of all varieties at each date of analysis are shown in Table II. These roots generally increased in carotene content the first 30 days of storage, then remained fairly constant.

An examination of Table II shows apparent differences in behavior among the different varieties. For instance, Danvers did not increase

in carotene at any period of storage, while Oxheart increased at both dates of analysis. These differences in behavior, however, are not statistically significant at the 5 per cent point.

### DISCUSSION

The apparent increase in carotene content with the maturity of the root, as shown by these experiments, generally agrees with the results published by other workers (6, 11, 15, 17) in that the carotene increases for approximately the first 100 days of growth, then remains fairly constant. The variations in the carotene content of roots of the same variety grown in different locations as reported in the literature (3, 4, 6, 15, 16) suggest that environmental factors were of greater importance than the varieties used. Probably some of this variation is due to differences in strains or lines of the same variety, and to differences in analytical methods used.

The increase in carotene content of the stored roots is in agreement only with investigators in New Mexico (1). Others (9, 10, 17) report no change in carotene content of stored roots, and Barnes (3) reports a decrease in storage up to 80 days. Differences in storage conditions perhaps influence changes in the carotene content. Further work will be done on this storage problem.

### SUMMARY

Varietal differences in carotene content were found among some of the carrot varieties tested. The carotene content of all varieties increased on a fresh weight basis up to approximately 100 days after planting, then remained fairly constant until harvested at 135 days. Differences in carotene content of any one variety, as based on reports by other workers at different locations indicate that environmental factors influence the carotene content.

In storage, the roots generally were found to have increased in carotene content on a dry weight basis at 30 days, then to have remained at the same level at 60 days.

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low slat-bottom flats. The bulbs were sorted at harvest to remove obvious culls and the samples were weighed and put into storage immediately. Samples of each stage of maturity were topped at 0, 1, 2 and 4 inches above the bulb in 1945 and 0, 2, and 4 inches in 1946. Fifty bulbs were used per sample in all cases except for Australian Brown when, because of their small size, 15 pound samples were used. For each stage of maturity 16 samples were used in 1945 and 12 in 1946. All samples were weighed on spring scales to the nearest 0.2 pounds. Decayed bulbs were removed, weighed and discarded several times during storage and the weight of the remaining sound bulbs was determined at the end of the storage period.

For Southport White Globe, 12 samples for each length of top were used in 1945, and eight samples in 1946. There were 12 samples for each length of top for the San Joaquin and eight for Australian Brown.

The data are presented as physiological loss, rot loss, and total loss (Tables I, II, and IV. Total loss was determined as follows: At the final weighing, rotten bulbs were discarded and the sound bulbs weighed. The percentage of sound bulbs remaining was subtracted

TABLE I—PERCENTAGE BREAK DOWN OF INITIAL WEIGHT OF TWO VARIETIES OF ONIONS HARVESTED AT THREE STAGES OF MATURITY AND TOPPED 0, 2, AND 4 INCHES FROM THE BULBS (STORED 10 WEEKS). ALL FIGURES ARE AVERAGES OF FOUR REPLICATES

Maturity*	Length of Topping (Inches)	Southport White Globe (1945)			San Joaquin (1946)			Southport White Globe (1946)		
		Physiological Loss (Per Cent)	Rot Loss (Per Cent)	Total Loss (Per Cent)	Physiological Loss (Per Cent)	Rot Loss (Per Cent)	Total Loss (Per Cent)	Physiological Loss (Per Cent)	Rot Loss (Per Cent)	Total Loss (Per Cent)
A	0	16.5	17.4	31.0	13.6	29.4	38.7	17.9	3.3	20.6
	2	18.2	63.9	70.3	14.1	35.2	44.3	17.1	14.4	29.0
	4	26.9	54.9	67.0	16.9	44.8	54.2	22.2	7.7	28.2
B	0	10.8	4.6	14.9	12.2	47.6	54.0	16.9	2.6	19.1
	2	13.1	42.7	50.8	11.6	34.8	42.3	10.5	3.2	13.4
	4	15.8	31.6	42.4	13.2	34.9	43.8	12.4	7.8	19.2
C	0	9.5	15.1	23.2	10.2	35.8	42.3	—	—	—
	2	14.2	27.8	38.7	12.9	33.6	42.2	—	—	—
	4	13.5	29.2	38.8	11.9	33.4	41.4	—	—	—
Difference required for odds 19:1		3.7	9.0	9.6	2.6	Not sig.	Not sig.	2.4	6.3	6.8

\*A = tops up and green.

B = tops down and green.

C = tops down and dry.

from 100 to obtain the percentage of the total loss. This value is expressed on an original fresh weight basis. Physiological loss was measured as weight loss due to water and respiration losses only. It consists of the difference between the initial weight of a sample and its final weight of both rots and sound bulbs. Since no actual data are available on the relative weight loss of sound versus rotten bulbs the assumption is made that they both lose weight at the same rate when calculating the physiological loss as a percentage of the original fresh

weight of the sample. Rot loss was arrived at by determining the percentage of the final weight of the sample which had to be discarded because of rot. Bulbs were considered rotten when an area 1 inch or more in diameter became broken down and soft. It follows from the above that the total loss is not numerically equal to rot loss plus physiological loss. Consider, for example, a sample of 100 pounds of onions which lose during storage, 50 per cent by physiological loss and 50 per cent by rot loss. The total loss in this case is obviously not 100 per cent but only 75 per cent since the rot consists of 50 per cent of the 50 pounds remaining after physiological shrinkage. All experimental results are tabulated in Table I except that for Australian Brown bulbs, omitted because of no rot loss. To compare harvest maturities all samples were averaged regardless of top length (Table II). To compare the effect of different top length all samples of the same top length and variety were averaged regardless of maturity (Table IV). All data were treated by analysis of variance (6) and where possible significant differences are indicated with odds of 99:1. Where thus indicated and no significant results apparent, neither are there significant differences at odds of 19:1. In Table I the differences required for odds of 19:1 are given since most of the differences were not significant at 99:1.

## RESULTS

*Stage of Maturity*.—The Southport White Globe onions cured in 1945 showed less physiological shrinkage for maturity C than for maturity B and for B less than A. There were no differences in rot loss between C and B, but both C and B were lower than A. The same relation held for total loss as for physiological loss (Table II).

TABLE II.—PERCENTAGE BREAKDOWN OF INITIAL WEIGHT OF THREE VARIETIES OF ONIONS, HARVESTED AT THREE STAGES OF MATURITY, AFTER TEN WEEKS IN STORAGE

Variety	Maturity*	Physiological Loss (Per Cent)	Rot Loss (Per Cent)	Total Loss (Per Cent)
1945 Southport White Globe	A	19.7	43.3	54.6
	B	12.7	26.3	35.6
	C	8.2	22.2	28.6
Difference required for odds 99:1		2.1	5.5	5.0
1946 Southport White Globe	A	19.0	8.5	25.9
	B	13.2	4.6	17.2
	C			
Difference required for odds 99:1		2.0	Not significant	5.4
San Joaquin	A	14.9	36.2	45.8
	B	12.3	39.2	46.7
	C	11.7	34.3	42.0
Difference required for odds 99:1		2.0	Not significant	Not significant
Australian Brown	A } B } C }	8.7 5.0 1.4	0 0 —	8.7 5.0 1.4
Difference required for odds 99:1				

\*A = tops up and green.  
B = tops down and green.  
C = tops down and dry.

Only maturities A and B were used for Southport White Globe onions in 1946. Physiological shrinkage and total loss were higher in maturity A than B while no difference was found for rot loss. With San Joaquin bulbs maturities B and C were both lower in physiological shrinkage than A. There were no differences between B and C for physiological shrinkage or between maturities A, B, and C for rot or total loss. With Australian Brown bulbs no rots developed during the storage period. A higher physiological shrinkage was found in maturity A and B than in maturity C with this variety.

None of the varieties formed roots in storage. Table III shows the formation of green shoots. Of the two varieties in which shoots did form one developed more shoots among maturity A and the other variety more shoots among maturity C. The data indicate no clear cut correlation between stage of maturity and subsequent formation of green shoots.

TABLE III—FORMATION OF GREEN SHOOTS AFTER TEN WEEKS STORAGE BY THREE VARIETIES OF ONIONS HARVESTED AT THREE STAGES OF MATURITY

Variety	Year	Maturity*	Percentage of Bulbs Showing Shoot Formation
Southport White Globe	1945	A	7.1
		B	6.8
		C	3.4
San Joaquin	1946	A	0.7
		B	1.5
		C	4.7
Southport White Globe	1946	No shoots formed	—
Australian Brown	1946		

\*A = tops up and green.

B = tops down and green.

C = tops down and dry.

*Length of Topping:*—The results are shown in Table IV. Southport White Globe onions were used in 1945. Topping at 0- and 1-inch showed no difference for physiological loss, but 2-inch topping showed greater loss than either, while 4-inch topping showed an increased loss over 2 inches. On rot loss, 1-inch showed a higher loss than 0, and 2-inch showed a higher loss than either 1 or 4. For total loss, 1-inch showed a higher loss than 0, while 2- and 4-inch toppings showed higher losses than 1, all differences being highly significant. No difference between 2- and 4-inch topping were found for total loss.

For all three varieties used in 1946, Southport White Globe, San Joaquin, and Australian Browns, significant differences between top lengths, were found for physiological shrinkage. With the exception of Southport White Globe bulbs in which 0- and 4-inch toppings showed higher physiological loss than 2-inch topping, all other varieties showed the highest losses with 4-inch topping. There were no significant differences between length of toppings for rot or total loss.

*Interaction Between Top Length and Maturity:*—From Tables I and II it can be seen that in several instances there were no significant differences between the various losses attributable to length of neck

TABLE IV—PERCENTAGE BREAKDOWN OF INITIAL WEIGHT OF THREE VARIETIES OF ONIONS TOPPED AT 0, 2, AND 4 INCHES FROM THE BULB AND STORED TEN WEEKS

Variety	Year	Length of Neck (Inches)	Physiological Loss (Per Cent)	Rot Loss (Per Cent)	Total Loss (Per Cent)
Southport White Globe	1945	0	12.3	12.3	23.1
		2	15.2	45.0	53.3
		4	18.7	37.8	49.4
		Difference required for odds 99:1	2.4	6.3	5.8
Southport White Globe	1946	0	17.4	3.3	19.9
		2	13.8	8.6	21.2
		4	17.3	7.7	23.7
		Difference required for odds 99:1	2.4	Not significant	Not significant
Australian Brown	1946	0	6.3	0	6.3
		2	5.5	0	5.5
		4	8.7	0	8.7
		Difference required for odds 99:1	1.7	—	1.7
San Joaquin	1946	0	12.0	37.5	45.0
		2	12.5	34.4	42.6
		4	14.0	37.7	46.5
		Difference required for odds 99:1	2.0	Not significant	Not significant

or time of maturity. In these cases and all others, except Australian Brown, a highly significant interaction between time of maturity and length of topping was found. The significance of this interaction lies in pointing out that for any one length of topping, losses will vary depending on the maturity. The interactions of maturity and length of neck are plotted against total loss, rot loss and physiological shrinkage in Fig. 1. From these graphs certain generalities are drawn. For maturity A, 0-inch topping was superior to 2- or 4-inch topping in reducing rot and total loss, while 0- and 2-inch topping resulted in the least physiological shrinkage. With maturity B the effect of length of topping was very inconsistent as would be expected because of the greater variability of maturity within class B than in class A or C. Bulbs harvested at maturity C showed fairly consistent losses regardless of length of topping.

## DISCUSSION

The results presented stress three factors which affect storage losses: first, the time of maturity at harvest; second, length of topping; and third, interaction between time of maturity and length of topping. Onions are extremely variable in their keeping quality within a variety. Between individual samples within a treatment rot losses often varied 100 per cent or more. On the other hand physiological losses in all cases were remarkably consistent. For these reasons the means of physiological losses in all cases showed highly significant differences while rot losses and total losses showed significant differences only occasionally.

The lack of green shoot formation may be attributed to the short storage period, and lack of roots to low humidity. In no case did more rot or physiological loss occur on bulbs topped at 0-inch than on bulbs with longer tops. However, these bulbs often became slightly more

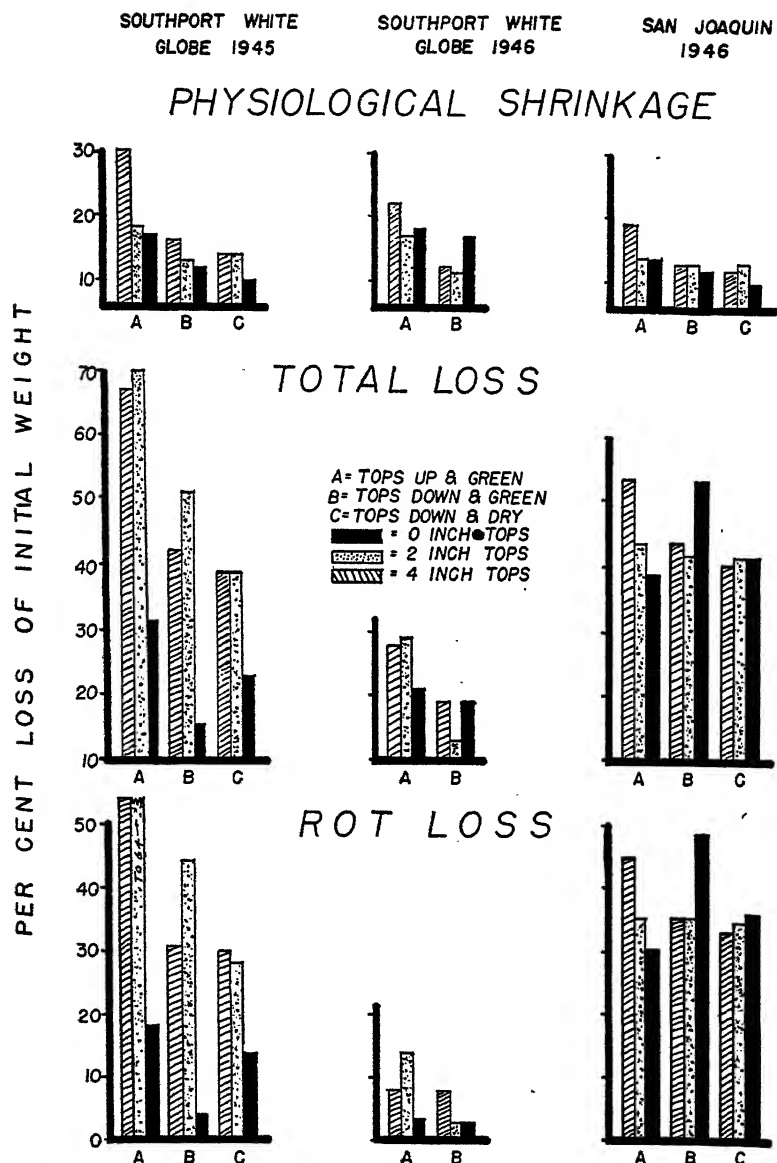


Fig. 1. Interaction between length of topping and time of maturity. All ordinates are per cent losses of initial weight and all abscissa are stages of maturity of onions.

shriveled than other treatments after several weeks in storage which was apparently due to the excess water loss in the vicinity of the open top. With some top left on the bulbs, the outer scales were apparently held in position and water loss was more uniform from the entire bulbs.

Length of top makes little difference on bulbs harvested when their tops are down and dry. This is to be expected since the moisture content of the bulb and tops have already reached a relatively low point. Bulbs harvested with tops up and green generally kept best with 0-inch topping. Since these bulbs are succulent, the short topping facilitated drying and eliminated the green matter of the tops. Inclusion of green tops is undesirable since they break down rapidly forming favorable conditions for rot organisms.

From unpublished data at this station it was determined that respiration loss may account for as much as 6 to 20 per cent of physiological loss over a 10-week storage period.

### SUMMARY

Studies of stage of maturity and length of topping as affecting storage quality were conducted at Davis in 1945 on Southport White Globe onions, and in 1946 on Southport White Globe, San Joaquin, and Australian Brown onions. All varieties were harvested at three stages of maturity, when possible, and topped at 0, 2, and 4 inches from the bulbs.

If maturity is considered independent of length of neck, physiological shrinkage was found to be highest among bulbs harvested with tops up and green, intermediate for bulbs harvested with tops down and green, and lowest for those harvested with tops down and dry. Rot and total losses were always lowest for bulbs harvested with tops down and dry, and highest for bulbs harvested with tops either down and green or up and green.

If length of topping is considered independent of maturity the shorter toppings usually resulted in the least physiological shrinkage and generally less rot and total loss. Topping flush with the bulbs usually resulted in an increased shrivelling of the bulbs but rotting was generally less than for bulbs receiving longer toppings.

An interaction was found to exist between length of topping and maturity. When harvesting bulbs with tops up and green a short topping length was found to be superior while for bulbs harvested with tops down and dry the topping lengths had little influence on subsequent storage behavior. Results for bulbs harvested with tops down and green were not consistent.

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# The Effect of Various Levels of Nitrogen and Potash on the Yield and Keeping Quality of Onions<sup>1</sup>

By ROBERT KUNKEL, *Colorado A. and M. College, Ft. Collins, Colo.*

MANY onion fertilizer experiments have been conducted, but as far as the author is able to ascertain no one has on an extensive scale carried the resulting bulbs through a storage period in order to determine the effect on keeping quality.

It was the purpose of the experiments herein reported to (a) determine whether or not the yield and keeping quality of onions could be influenced by varying both the amount and the time of application of nitrogen and potash under field conditions; and (b) to determine the relationship between size of bulb and keeping quality.

## EXPERIMENTAL PROCEDURE

*Field Experiments:*—A total of four field experiments were conducted in New York State. Two of them were on the Elba and two of them were on the Oswego peat soil areas.

The 1943 and 1944 Elba experiments were conducted on soils which had been under cultivation for 2 years and which would be classed as deep, well drained woody mucks. The field used in 1943 had been fertilized the 2 years previous with 850 pounds per acre of a 0-20-20 fertilizer and in 1942 had also received 200 pounds per acre of copper and manganese sulfates which were mixed in equal proportions. The field used in 1944 had been fertilized the 2 years previous with about 1500 pounds per acre of a 5-10-10 fertilizer which contained some copper.

The 1943 and 1944 Oswego experiments were conducted on soils which had been under cultivation 12 and 15 years respectively. Both were deep woody mucks but the one used in 1944 was better drained and less acid than the soil used in 1943 (Table I).

The following six treatments were used both years at Elba and Oswego, each treatment replicated five times:

Treatment No.	Pounds N.	Pounds $P_2O_5$	Pounds $K_2O$
1	0	80	120
2	40	80	0
3	40	80	120
4	80	80	240
5	40 + 20*	80	120
6	40 + 20*	80.	120 + 60*

\*Amount applied as a side dressing.

The fertilizer was mixed by hand. One-half of the nitrogen was from ammonium sulfate. The remainder was supplied equally by nitrate of soda and urea. Superphosphate was used as the source of phosphorus and muriate of potash as the source of potash. Ground limestone was added to neutralize the acidity of the fertilizer.

<sup>1</sup>Paper No. 288. Department of Vegetable Crops, Cornell University, Ithaca, New York.



The fertilizers were broadcast by hand after which they were disked in and the ground leveled and finished off with a float, care being taken to go lengthwise of the plots.

Data concerning size of plot, variety, pH of the soil, and dates of harvest and storage are given in Table I.

At harvest time the onions were pulled and topped with shears directly into crates. Within 2 weeks after harvest, the bulbs were graded into U. S. No. 1's, 2's and culls. The number of bulbs in each grade were then counted and weighed and a random sample for storage taken from each plot.

TABLE I—DETAILS OF METHODS

Place	Year	Size of Plot (Ft)	Distance Between Rows (Ins)	Date Fertilized and Planted	Variety*	Date of Side-dressing	Date Harvested	pH of Soil at End Season	Date Stored	End of Storage
Elba	1943	15×15	14	Apr 29	Early Yellow Globe	Jun 23	Aug 24	6.0	Oct 20	Apr 5
Elba	1944	10×20	14	Apr 28	Early Yellow Globe	Jun 22	Aug 21	6.2	Oct 4	Feb 28
Oswego	1943	15×15	16	May 5	Brigham	Jun 25	Aug 18	5.2	Oct 20	Apr 5
Oswego	1944	10×20	16	Apr 29	Brigham	Jun 13	Aug 15	5.5	Oct 4	Apr 10

\*Elba 1943 Kaczmareczky's strain of Early Yellow Globes.

Elba 1944 Woodruff's strain of Early Yellow Globe.

Oswego 1943 Harris' strain Michigan Yellow Globe.

Oswego 1944 Harris' strain Michigan Yellow Globe.

**Storage:**—Approximately 1 bushel of the U. S. No. 1 grade of onions was taken from each plot and trucked to Ithaca for storage. After curing the bulbs were sorted and weighed and placed in storage at 40 degrees F. This temperature was selected in order to subject the bulbs to somewhat adverse conditions in order to bring out differences between treatments before spring work in the field made the job of sorting difficult.

The onions were weighed and sorted at intervals of from 1 to 2 months. A record was made of the number of the decaying, sprouting, and rooting bulbs and then they were discarded. Bulbs with both sprouts and roots were counted as sprouts.

In order to obtain data on effect of size of bulb on keeping quality, in 1944, 3 bushels of onions under 2 inches in diameter (300 bulbs/bushel) and an equal quantity of bulbs over 2½ inches in diameter (138 bulbs/bushel) were selected in a field adjacent to the Elba fertilizer plot. The muck had been fertilized with 1500 pounds of 5-10-10 to the acre. The variety was Early Yellow Globe. These onions were stored in the same manner as those from the fertilizer experiment.

In all of the work except in the case of losses due to size of bulb, the analysis of variance method was used in determining the significance or lack of significance of data.

## RESULTS

**The Effect of Fertilizer Treatment on Yields:**—Yield data from the various plots are given in Table II. In the Elba experiment in

1943 treatment 4 outyielded treatment 1 by odds of greater than 99:1 and outyielded treatment 6 by odds of 19:1. Treatment 5 outyielded treatment 1 by odds of 19:1.

TABLE II—YIELD OF ONIONS IN POUNDS PER PLOT AT ELBA AND OSWEGO, NEW YORK IN 1943 AND 1944

Place	Treatments						M.S.D.	
	1	2	3	4	5	6	5 Per Cent	1 Per Cent
Elba, 1943*.....	122.4	125.2	125.6	130.2	128.7	124.8	5.13	6.96
Oswego, 1943.....	39.3	74.4	70.0	89.9	87.5	87.9	10.90	14.80
Elba, 1944†.....	131.7	130.4	129.0	131.9	126.1	128.5	—	—
Oswego, 1944.....	79.2	75.4	78.9	83.1	81.0	79.5	—	—

\*1943 pounds/plot  $\times 5.04$  equals approximate number of 60-pound bushel per acre.

†1944 pounds/plot  $\times 6.14$  equals approximate number of 60-pound bushel per acre.

In the Oswego experiment in 1943, there was a great difference in the size and color of the plus and the minus nitrogen plots at the time that the plots that received treatments 5 and 6 were sidedressed (June 25). The differences persisted until harvest time. The minus nitrogen plots showed a large amount of dying at the tips of the tops. At harvest time the roots of the onions in the minus nitrogen plots were still white and firmly attached to the bulbs while those in the plus nitrogen plots were dead and separated easily.

The data in Table II (Oswego, 1943) indicates that treatments 2, 3, 4, 5, and 6 were better than treatment 1 by odds of much greater than 99:1. Treatment 4 was better than treatments 2 and 3 by odds greater than 99:1. Treatments 5 and 6 were better than treatments 2 and 3 by odds greater than 19:1, but there was no significant difference between treatments 4, 5, and 6. These data show that the major response was due to nitrogen, there being no difference in yield between no potash, 120 pounds and 180 pounds per acre when nitrogen and phosphorus remained constant.

The 1944 experiments did not show significant differences in yields between treatments at either Elba or Oswego (Table II).

*The Effect of Various Levels of Nitrogen and Potash on the Keeping Quality of Onions:*—During the course of these experiments it was found that under the conditions of the experiment the primary loss in storage was due to sprout and root formation, the amount of decay and loss in weight being negligibly small by comparison both years. No statistically significant difference in loss of weight or number of decays was found for any treatment either year so the data are not included.

The effect of sprouting and rooting was not considered separately in the analysis of variance of the data because bulbs which showed both sprouts and roots were classed as sprouts. The mean weekly temperature and per cent relative humidity throughout the storage periods are given in Figs. 1 and 2.

In the Elba experiment in 1943 as shown in Table III, bulbs from treatment 1 sprouted and rooted less than those from treatment 5 by odds of 19:1 and those from treatment 4 sprouted and rooted less

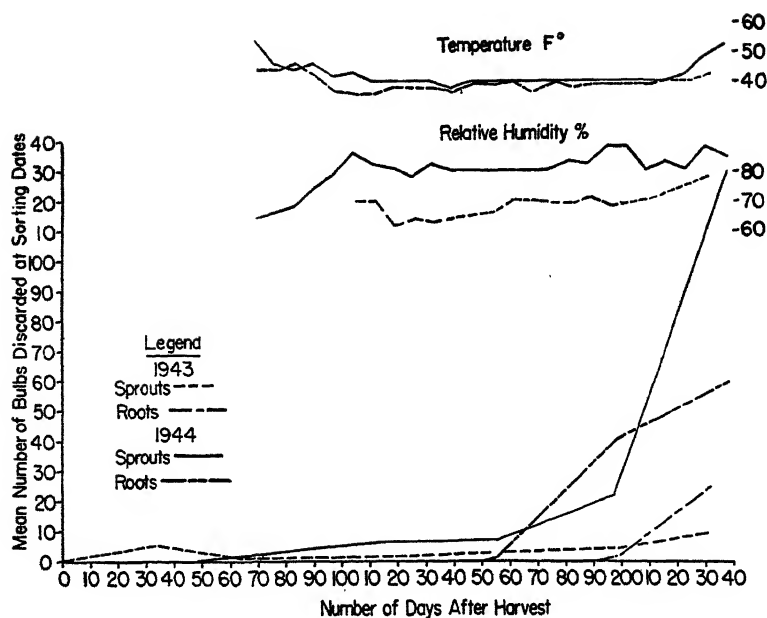


FIG. 1. Storage losses by sorting dates of Brigham Yellow Globe onions during 1943 and 1944.

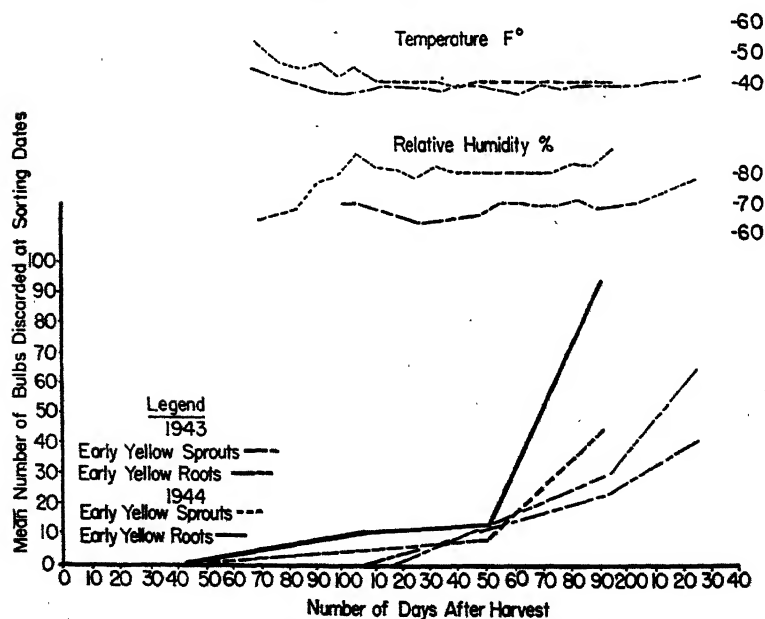


FIG. 2. Storage losses by sorting dates of Early Yellow Globe onions during 1943 and 1944.

TABLE III—PER CENT OF THE TOTAL NUMBER OF ONION BULBS STORED, DISCARDED BECAUSE OF ROOT AND SPROUT FORMATION AT TERMINATION OF EXPERIMENT

Year and Source of Bulbs	Treatment						Number Days Between Harvest and End of Experiment	LX. X
	1	2	3	4	5	6		
✓ Elba 1943.....	59.9*	63.4	61.1	58.0	66.0	63.0	225	19:1-5.76 99:1-7.82 X
✓ Elba 1944.....	42.3	44.7	42.3	42.7	45.9	42.9	191	
✓ Oswego 1943.....	19.1	11.2	16.2	17.7	17.3	13.9	231	19:1-4.4 99:1-5.9 X
✓ Oswego 1944.....	87.5	91.7	90.5	92.3	90.9	89.7	238	

\*Each figure is the mean of five replications, each consisting of a bushel of onions.

than those of treatment 5 by odds greater than 99:1. None of the other comparisons was significant.

These data indicate that nitrogen applied as a sidedressing without potash was more detrimental to the keeping quality than was growing the onions on a relatively high nitrogen application when applied at planting time. The least amount of loss resulted from the onions grown on the highest amount of fertilizer when applied at planting time.

In the 1943 Oswego experiment, there were fewer sprouted and rooted bulbs in treatment 2 than in treatments 1, 4 and 5 by odds of 99:1 and fewer than in treatment 3 by odds of 19:1. Treatment 6 had fewer sprouting and rooting bulbs than treatment 1 by odds of 19:1. None of the other comparisons was significant.

In the 1944 experiments there were no significant differences in sprouting or rooting of bulbs from the different treatments in either Elba or Oswego.

As shown in Table IV no significant difference was obtained in the experiment with bulbs of large and of small size.

TABLE IV—THE EFFECT OF SIZE OF BULB ON THE RATE OF ROOT AND SPROUT FORMATION IN STORAGE LISTED BY SORTING DATES

Size	Accumulative Loss Due to Sprouting (Per Cent)				Accumulative Loss Due to Rooting (Per Cent)				Loss Total (Per Cent)
	Oct 2	Dec 6	Jan 17	Feb 28	Oct 2	Dec 6	Jan 17	Feb 28	
Small bulbs	0.55	4.89	9.11	27.33	0.00	7.67	12.44	59.00	86.33*
Large bulbs	0.72	4.59	6.52	29.95	0.00	2.66	12.08	60.87	90.52

\*T = .552

2.776 needed for odds of 19:1

## DISCUSSION

In these experiments effect of fertilizer treatment on the keeping quality were variable. At Elba in 1943 the heaviest application of both nitrogen and potash gave the smallest loss due to sprouting and rooting bulbs. The same year at Oswego with a different variety and under different soil conditions the greatest losses in storage resulted

from the heaviest applications of nitrogen and potash. There is an indication, though not statistically significant, that nitrogen when added as a sidedressing without potash tended to decrease the keeping quality. Hawthorne (19) in 1932 working on a mineral soil in Texas found a correlation between high fertilization, particularly high nitrogen and poor keeping quality, but in 1933 the trend was not clear. In a later series of experiments covering a period of 2 years he concluded potash had a variable effect on keeping quality.

Wright, *et al* (10) found that sprouting in stored onions was influenced very slightly by humidity but increased with increased temperature, while rooting increased with increased humidity and was but little influenced by increase in temperature. Figs. 1 and 2 show that the mean storage temperatures in 1943 and 1944 were essentially the same except for the last 2 weeks of the storage period in 1944, during which time it was 10 degrees F higher than in 1943. This seems to have caused a rapid increase in the number of shoots over roots in the Brigham variety, but this is not necessarily the case since bulbs with both shoots and roots were classed as shoots. Under the storage conditions some bulbs formed only shoots, others only roots, others both roots and shoots and still others had formed neither at the termination of the experiment.

The mean weekly humidity in 1944 was generally about 10 per cent higher than in 1943, and in the Early Yellow variety there were considerably more bulbs with roots than sprouts which might lead one to conclude that the Brigham variety is less susceptible to high storage humidity than the Early Yellow variety.

In line with the observations of New York growers and with the findings of Magruder *et al* (8) the Brigham variety kept better in storage than the Early Yellow Globe.

#### SUMMARY

Onions of the Early Yellow variety were grown 2 years on muck which had been under cultivation 2 years. Onions of the Brigham variety were grown 2 years on muck which had been under cultivation 12 years or more. The same fertilizer treatments were used for both varieties both years and each year approximately a bushel sample from each plot was stored at Ithaca to determine the effect of the fertilizer treatments on keeping quality.

Two sizes of bulbs of the Early Yellow variety were compared as to keeping quality.

1. During neither year on either the 2-or 12-year-old muck was there an increase in yield due to potash.

2. During the cold wet spring of 1943 nitrogen increased the yield on both the 2-year-old and the 12-year-old muck but was especially beneficial on the low pH 12-year-old muck.

3. In 1943 nitrogen applied as a side dressing increased the yield on both the 2-year-old and the 12-year-old mucks but gave indication that when added without potash it tended to decrease the keeping quality.

4. The effect of various levels of nitrogen and potash on keeping quality is not clear. In 1943 the bulbs from the Elba plots which received the highest rate of nitrogen and potash kept the best while the reverse was true of the onion from Oswego except where an acute nitrogen deficiency existed. In 1944 none of the treatments caused a statistically significant difference in keeping quality even though mineral nutrients were present in excess.

5. There was no statistically significant difference between the losses due to sprout and root formation attributable to size of bulb.

6. The primary loss in storage was due to sprout and root formation and not to loss in weight or decay.

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## Sweet Corn Variety Testing in Mississippi<sup>1</sup>

By J. L. BOWERS, *Mississippi Agricultural Experiment Station, State College, Miss.*; T. E. ASHLEY, *South Mississippi Branch Experiment Station, Poplarville, Miss.*; J. A. CAMPBELL, *Truck Crops Experiment Station, Crystal Springs, Miss.*; M. T. DEONIER, *U. S. Horticultural Field Station, Meridian, Miss.*; and L. R. FARISH, *Delta Experiment Station, Stoneville, Miss.*

THE state-wide program of testing sweet corn varieties in 1946 was conducted by experiment stations at State College, Stoneville, Poplarville, Crystal Springs, and by the United States Horticultural Field Station at Meridian, Mississippi. The program was planned to test the adaptability of several hybrids to different soil and climatic conditions in Mississippi. The Truckers Favorite variety, a field corn type grown in the south for fresh roasting ears, and Golden Cross Bantam (a true sweet corn type) were grown in each test (and used as checks as a means of measuring the performance of the other varieties).

### METHODS OF TESTING

The randomized block lay-out was employed at each location. Each variety was replicated five times, and at three locations the plot size was two rows, 20 feet in length. At the other two locations the plot size varied, but a factor was used in converting the yield to a common basis for all stations.

The corn was harvested in the roasting ear stage which was determined by each cooperator at each station. The thumb nail test was employed in determining this stage of maturity. The ears were classed into marketable ears and culls in the tests at State College, Meridian, and Stoneville. Ears which had 6 inches of good kernels after the ear worm damage had been trimmed off, were classed as "marketables". Total yield records were obtained at four locations, namely, State College, Meridian, Poplarville, and Crystal Springs. Records on the weight of marketable corn as well as number of ears were taken on 19 varieties in the tests at State College and Meridian.

The studies on corn ear worm damage were conducted at Crystal Springs, Meridian, and Poplarville Stations. The worm damage found on each ear of corn at Crystal Springs and Poplarville Stations was given a numerical value on the basis of its extent, as follows:

- 0—No ear worm damage
- 1—Less than 1 inch of tip damaged
- 2—Between 1 and 2 inches of tip damaged
- 3—Between 2 and 3 inches of tip damaged
- 4—Between 3 and 4 inches of ear damaged
- 5—Entire length of ear damaged

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<sup>1</sup>Research Paper No. 156, Department of Horticulture. Published with the approval of the Director, Agricultural Experiment Station.

The data taken on ear worm in the Meridian test was on the same basis, but only 20 ears from each variety at random were scored. The average index for the 20 ears was recorded.

### RESULTS

The Tristate variety led in total yield in three out of four locations as shown by the data in Table I. The average yield of this variety

TABLE I—SWEET CORN VARIETY TRIALS IN MISSISSIPPI (SPRING 1946)\*

Varieties	Crystal Springs	Meridian	Poplarville	State College	Average
Tristate.....	1,590	1,566	1,115	1,824	1,524
Aristogold Bantam No. 2.....	1,940	1,436	1,011	1,446	1,458
Illinois Golden No. 10.....	1,600	1,488	1,063	1,415	1,392
Golden Hybrid 2439.....	1,485	1,244	1,028	1,607	1,341
Goldengrain.....	1,555	1,410	1,011	1,296	1,318
Aristogold Bantam No. 1.....	1,345	1,437	1,080	1,101	1,241
Golden Cross Bantam.....	1,387	1,561	890	1,109	1,237
Ioana.....	1,415	1,384	786	1,161	1,187
Truckers Favorite.....	1,125	1,053	873	1,503	1,138
Oto.....	1,455	1,482	726	866	1,127
Tendermost.....	1,180	1,182	821	949	1,023
Aristogold Bantam No. 3.....	1,235	1,069	769	959	1,008
Pontiac.....	1,080	970	830	917	949
Topflight Bantam.....	895	850	614	1,081	860
Difference required for significance between varieties.....	290	233	229	414	150
Difference required for significance between varieties.....	382	307	302	544	197

\*Total yield expressed in dozen ears per acre.

from the four locations was significantly higher than the average yield from any other variety in the test, with the exception of Aristogold Bantam No. 2, Illinois Golden No. 10, and Golden Hybrid 2439. The difference in yield between any two of these four leading varieties was not great enough to be considered statistically significant. The average yield of Golden Cross Bantam from four locations (standard by which most varieties are compared) was surpassed only by the yield of Tristate, Aristogold Bantam No. 2, and Illinois Golden No. 10. The yield from Golden Cross Bantam was superior to the yield from each of four varieties, namely, Tendermost, Aristogold Bantam No. 3, Pontiac, and Topflight Bantam.

The interaction between places and varieties is significant, which means that varieties in this test responded differently in each location. For instance, Tristate, the leading variety which produced the highest average yield from four locations as shown in Table I, ranked third in production at Crystal Springs and first at the other three stations by a significant difference. The performance of Aristogold Bantam No. 2 was even more variable under different soil and climatic conditions. This variety ranked first in the Crystal Springs test, fifth in the Meridian test, fifth in the Poplarville test, and fourth in the State College test. Aristogold Bantam No. 2 produced 1,940 dozen ears per acre in the Crystal Springs test which was significantly higher than the yield produced by any other variety in the test, and the yield from this variety in the State College test was significantly lower than the yield of Tristate.

The data on yield of marketable ears was obtained at Stoneville,



Meridian, and State College, and the results from these tests are presented in Table II. Tristate and Aristogold Bantam No. 1, the two leading varieties, produced an average yield of 1,213 and 1,095 dozen

TABLE II—SWEET CORN VARIETY TRIALS IN MISSISSIPPI (SPRING 1946)\*

Varieties	Meridian	Stoneville	State College	Average
Tristate	1,328	1,165	1,145	1,213
Aristogold Bantam No. 1	1,172	1,351	763	1,095
Aristogold Bantam No. 2	1,203	1,044	793	1,013
Ioana	1,167	943	726	945
Golden Cross Bantam	1,286	949	534	923
Aristogold Bantam No. 3	965	1,013	741	906
Tendermost	1,022	878	606	835
Truckers Favorite	866	749	860	825
Topflight Bantam	716	928	610	751
Difference required for significance 19:1	212	212	263	132
Difference required for significance 99:1	279	279	346	174
Difference required for significance (varieties by places)		19:1	229	
Difference required for significance (varieties by places)		99:1	301	

\*Yield of marketable ears, expressed in dozen ears per acre.

marketable ears per acre, respectively, in these tests. The yield from Tristate was significantly higher than the yield from all other varieties in the test with the exception of Aristogold Bantam No. 1. Golden Cross Bantam produced an average yield of 923 dozen ears per acre, and this yield is only significantly outclassed by the yield of Tristate and Aristogold Bantam No. 1. Truckers Favorite was badly outclassed by Tristate, Aristogold Bantam No. 1 and Aristogold Bantam No. 2 in tests at two locations. Ioana produced 120 dozen ears per acre more than were produced by Truckers Favorite, and this value approaches statistical significance.

In the analysis of the data on yield of marketable ears the interaction of places and varieties is, again, significant, as it was for total yield. Aristogold Bantam No. 1, which ranked first in the test at Stoneville, placed fourth in the tests at Meridian and State College. A still more striking picture is presented by the performance of Truckers Favorite under different growing conditions. This variety ranked second in the test at State College and eighth and ninth in the Meridian and Stoneville tests, respectively.

Data on the weight of marketable ears were secured at State College and Meridian. Tristate was, again, the leading variety in number of marketable ears produced, but it ranked third in weight of corn produced, preceded by Iogreen 56 and Truckers Favorite. Iogreen 56, which produced the highest yield in weight (8,677 pounds per acre), was significantly lower in number of ears than any one of the four leading varieties: Tristate, Illinois Golden No. 10, Goldenrain, or Golden Hybrid 2439. Yield of Iogreen 56 in weight of corn was not significantly different from that of any one of the five leading varieties presented in Table IV, when the comparisons are made between average yields from the two locations.

Average ear weight is not a true index to ear size because some varieties produce relatively thick short ears with large cobs, as shown

by the Pontiac variety (1.02 pound per ear). Other varieties produce a very thin long ear (small cob), as the Aristogold Bantam No. 1, which averaged only 0.52 pounds per ear. The average ear size of the five leading varieties (based on total number of ears) varied from 0.67 to 0.78 pounds. These data indicate that the varieties better adapted to Mississippi conditions produce medium-size ears.

The data presented in Table IV show that Oto produced ears which

TABLE III—YIELD OF MARKETABLE SWEET CORN FROM NINETEEN VARIETIES AT TWO LOCATIONS, NAMELY, STATE COLLEGE AND MERIDIAN, (SPRING 1946)

Varieties	State College		Meridian		Average Yield		Average Ear Weight (Pounds)
	Dozen Ears Per Acre	Pounds Per Acre	Dozen Ears Per Acre	Pounds Per Acre	Dozen Ears Per Acre	Pounds Per Acre	
Tristate.....	1,145	7,993	1,328	8,708	1,237	8,335	0.67
Illinois Golden No. 10.....	943	6,998	1,307	9,610	1,125	8,304	0.74
Goldengrain.....	897	6,813	1,327	10,201	1,112	8,242	0.74
Golden Hybrid 2439.....	1,094	7,713	1,027	7,495	1,060	7,588	0.72
White Kernel Golden Cross.....	793	6,220	1,275	9,952	1,034	8,086	0.78
Aristogold Bantam No. 2.....	793	5,163	1,203	7,433	998	6,313	0.63
Aristogold Bantam No. 1.....	763	3,950	1,172	6,189	967	5,069	0.52
Ioana.....	726	4,883	1,167	7,682	946	6,282	0.66
Golden Cross Bantam.....	534	3,608	1,286	7,868	910	5,754	0.63
Oto.....	554	3,514	1,234	7,371	894	5,443	0.61
Golden Evergreen Hybrid.....	669	5,225	1,099	7,931	884	6,593	0.75
Truckers Favorite.....	860	8,024	866	9,112	863	8,584	0.99
Aristogold Bantam No. 3.....	741	5,225	965	6,624	853	5,909	0.69
Iogreen 56.....	663	6,376	1,037	10,978	850	8,677	1.02
Hickory King.....	710	6,313	928	8,584	819	7,433	0.91
Tendermost.....	606	3,763	1,022	5,785	814	4,789	0.59
Topflight Bantam.....	610	4,199	716	4,447	663	4,323	0.65
Mammoth Golden.....	539	3,545	741	4,727	640	4,136	0.65
Pontiac.....	342	3,203	622	6,624	482	4,914	1.02
Difference required for significance odds 19:1.....	335	2,383	208	1,512	200	1,457	
Difference required for significance odds 99:1.....	441	3,137	273	1,990	263	1,918	

TABLE IV—EAR WORM DAMAGE IN FOURTEEN VARIETIES OF SWEET CORN TESTED AT THREE LOCATIONS IN MISSISSIPPI, SPRING 1946, (AVERAGE INDEX NUMBERS INDICATING APPROXIMATE EXTENT OF INJURY FROM TIP OF EARS)

Varieties	Crystal Springs	Poplarville*	Average Damage for Two Stations	Meridian**
Oto.....	1.11	1.53	1.32	1.5
Illinois Golden No. 10.....	1.51	1.84	1.68	1.7
Golden Hybrid 2439.....	1.79	1.66	1.73	1.9
Ioana.....	1.49	1.99	1.74	1.9
Aristogold Bantam No. 3.....	1.64	1.95	1.79	1.8
Golden Cross Bantam.....	1.46	2.19	1.83	1.7
Aristogold Bantam No. 1.....	1.44	2.35	1.89	1.8
Aristogold Bantam No. 2.....	1.88	1.91	1.90	1.8
Topflight Bantam.....	1.54	2.26	1.90	1.8
Goldengrain.....	1.53	2.36	1.94	2.1
Tendermost.....	1.82	2.08	1.95	2.5
Tristate.....	1.86	2.14	2.00	2.0
Truckers Favorite.....	1.61	2.39	2.00	1.9
Pontiac.....	1.61	2.51	2.06	2.3
Average damage of all varieties.....	1.59	2.08	—	1.9
Difference required for significance Odds 19:1.....	0.18		0.33	
Difference required for significance Odds 99:1.....	0.23		0.44	

\*Differences between indexes at Poplarville are not significant.

\*\*Data from Meridian did not lend itself to statistical analysis.

had significantly less ear worm damage than ears harvested from any other variety when the average damage at both stations is considered. The average ear worm damage in Illinois Golden No. 10 and in Golden Hybrid 2439 was significantly less than the damage found on ears of the Pontiac variety. This damage, however, was not significantly less than the damage found on ears in other varieties in the test.

The results obtained at each station when considered separately are strikingly different. Oto showed a significantly less degree of ear worm damage than was exhibited by any other variety in the test at Crystal Springs. Ears of Golden Hybrid 2439, Tendermost, Tristate, and Aristogold Bantam No. 2 showed the greatest amount of worm damage in the test at Crystal Springs. Worm injury on ears from these varieties was significantly greater than the injury found on Golden Cross Bantam ears. The large differences between indexes at Poplarville were not significant. The error of estimate was too great to permit an accurate estimate of differences. The data on ear worm damage from the Meridian test presents a similar picture to the one presented by the Crystal Springs data in some respects. For instance, the Oto variety showed the least amount of ear worm injury at both stations. Varieties that showed considerable injury in the Crystal Springs test were also damaged heavily in the Meridian test. The average corn ear worm index of 1.59 for all varieties in the Crystal Springs test was significantly less than that for all varieties in the Poplarville test (2.08). The average corn ear worm index for all varieties in the Meridian test was 1.9 which is slightly less than the injury found on ears in the Poplarville test.

### SUMMARY

Sweet corn varieties that have been tested in this state indicate great variability in the way in which they respond to different environments. From the results of the 1946 trials in Mississippi, it appears that Tristate is the most widely adapted variety. Furthermore, these trials indicate the importance of varietal adaptation for the different sections. These tests also showed Aristogold Bantam No. 2, Illinois Golden No. 10 and Golden Hybrid 2439 to be widely adapted. The first two varieties produced equally as well as the Tristate variety.

Iogreen 56, Pontiac, and Truckers Favorite, which produced the heaviest ears (average ear weight, 0.99 to 1.02 pounds), were significantly lower in total yield in number of ears than either Tristate, Illinois Golden No. 10, Goldenrain, or Golden Hybrid 2439, with one exception. Truckers Favorite did not significantly outyield Golden Hybrid 2439 in number of ears but the difference approached significance. The types producing the heaviest ears are not necessarily the most desirable ones, as is shown by the data presented.

Oto appeared to be less susceptible to ear worm damage than any other hybrid in these tests. This variety did not produce as high a total yield as several others in the test, but its productivity was equivalent to Golden Cross Bantam. Oto was outclassed in total yield by only five varieties, Tristate, Aristogold Bantam No. 2, Illinois Golden No. 10, Golden Hybrid 2439, and Goldenrain.

## Preliminary Studies on the Effects of Soil Applications of 2,4-D on Crop and Weed Growth<sup>1</sup>

By G. F. WARREN, K. P. BUCHHOLTZ, and T. P. HERNANDEZ,  
*University of Wisconsin, Madison, Wis.*

THE herbicidal action of 2,4-D (2,4-dichlorophenoxyacetic acid) and closely related compounds when applied as sprays to the above ground parts of plants has been widely studied. Although several workers have reported inhibition of seed germination in soils treated with these growth regulators (1, 2, 3, 4, 5, 7, 8, 9), this method of weed control has received much less attention than have spray applications to the foliage.

Slade, *et al* (9) and Blackman (2) reported that it takes about twice as much of the substituted phenoxy acetic acids when applied to the soil before emergence to be equivalent in herbicidal effect to spray applications made to above ground parts. The grasses have been found to be generally more resistant to soil treatments with growth regulators than the broadleaved plants (1, 2, 3, 5, 7, 9). On the other hand, Allard *et al* (1) point out that 2,4-D had a more general herbicidal effect on germinating seeds than on older plants and suggest that this may have practical applications in weed control. Hamner, *et al* (5) and Mitchell and Marth (7) suggested that weed seeds might be killed in muck, manure and soil by treatment with 2,4-D and weed free crops grown later.

The purpose of our experiments was to determine the effect of applications of 2,4-D to the soil under field conditions on weed control and on the germination and growth of certain vegetable crops. It seemed possible to control weedy grasses in the seedling stage with soil applications of 2,4-D whereas they are resistant to sprays applied to the foliage. Also, it appeared that weed control might be effected by this method in crops that are sensitive to applications of 2,4-D to the top growth.

### RESULTS IN 1945

An experiment was started May 18 on a silt loam soil at Madison, Wisconsin to study the residual effects of soil application of 2,4-D on the growth of nine crop plants each representing a different family. A preparation of the sodium salt of 2,4-dichlorophenoxyacetic acid<sup>2</sup> containing the equivalent of 70 per cent of the acid was applied as a spray to the soil surface. Duplicate plots were treated with varying quantities of a solution containing 1,000 parts per million of 2,4-D in water. The quantities used supplied the equivalent of 0, 1, 3 and 13 pounds of 2,4-D per acre.

Just before the treatments were made, a short row of each crop was planted at one end of every plot. A second planting was made 13 days later, and a third, 37 days after spraying the soil. Notes were taken

<sup>1</sup>Published with the permission of the Director of the Agricultural Experiment Station.

<sup>2</sup>Supplied by the Dow Chemical Company, Midland, Michigan.

frequently on emergence and estimates of stand and growth compared with the checks were made 37 to 39 days after planting.

The data in Table I show the effect of the treatments on germination and growth of four representative crops in the first and second plantings. The responses of flax, hemp, cabbage, tomatoes and beets were similar to those observed for onions. It will be noted that the

TABLE I—EFFECT OF 2,4-D SOIL TREATMENTS ON RATE OF EMERGENCE, STAND AND GROWTH OF CERTAIN CROPS IN 1945

Crop	Pounds 2,4-D Per Acre	Comparison With Check					
		Applied Immediately After Seeding			Applied Thirteen Days After Seeding		
		Delay in Emergence (Days)	Stand (Per Cent)	Growth (Per Cent)	Delay in Emergence (Days)	Stand (Per Cent)	Growth (Per Cent)
Carrots	1	12	40	20	0	60	100
	3	14	0	—	0	100	100
	13	—	0	—	0	100	100
Onions	1	7	40	20	0	100	100
	3	9	10	10	0	100	100
	13	7	10	10	0	100	100
Beans	1	0	80	60	0	100	100
	3	9	40	40	0	100	60
	13	8	20	20	2	80	20
Oats	1	0	100	100	0	100	60
	3	1	80	60	0	100	80
	13	1	60	20	0	100	80

stand and growth of all crops was reduced and emergence delayed by 2,4-D. The effect increased as the rate of application increased, but was not directly proportional to the amount applied. The crops varied in their susceptibility, carrots being most sensitive and oats most resistant.

The planting made 13 days after the soil was treated showed only minor effects indicating that most of the 2,4-D had disappeared. All crops were normal when planted 37 days after treatment. It should be pointed out that the soil was moist when the 2,4-D sprays were applied and that in the 2 weeks following treatment there was 1.51 inches of rainfall. These results are in agreement with those of other workers who have found that 2,4-D rapidly loses its toxicity in moist soil (4, 5, 7). Some of the 2,4-D may also have been lost by leaching. Both Hanks (6) and DeRose (4) found 2,4-D in the leachate from treated soils.

It was noted that there was a marked suppression of weed growth which was mostly foxtail (*Setaria spp.*) in this experiment. The effect increased with the higher rate of application. There were only a few weeds present on the plots receiving 3 pounds of 2,4-D per acre and at 13 pounds the plots were practically bare for 6 to 8 weeks after spraying when the soil was not disturbed. However, by October, these same undisturbed parts of the treated plots were as weedy as the checks, being indistinguishable from them. Apparently, weed seeds that were dormant early in the season germinated and grew normally later when the toxicity of the 2,4-D had disappeared.

A second experiment was conducted on peat soil to see if it might be possible to control weeds with 2,4-D soil treatments without damaging certain vegetable crops. Duplicate plots were sprayed July 24 with 120 gallons per acre of solutions of varying concentration to give 0, 1, 2, 4, and 8 pounds per acre of 2,4-D. The same preparation of 2,4-D was used as in the earlier experiment. Plantings of snap beans, beets, carrots and onions were made 0, 3, 7, 9, and 17 days after spraying.

Temperatures were too high for good germination of all crops except beans so it was impossible to obtain accurate stand counts. However, it was noted that the stands of beans were reduced less by 2,4-D than were the stands of the other crops. This is in agreement with the observations on the earlier experiment and with those of Crafts (3) who includes beans along with small grains, corn and milo as tolerant species. It was further noted that beans planted 0 and 3 days after treatment, germinated much better than those planted 7 days after treatment. The explanation appears to lie in the soil moisture conditions. In the first plantings the bean seeds were in moist soil and germinated rapidly, but the soil surface was dry and the 2,4-D applied undoubtedly remained on the surface. From the sixth to the eighth day after spraying the soil, there was 1.44 inches of rainfall which apparently washed the 2,4-D into the soil and thus greatly reduced the germination of the beans planted 7 days after treatment. The effect increased with rate of application. Later plantings showed progressively less injury. However, many of the beans that emerged on treated plots showed the virus-like symptoms reported by Hamner *et al* (5).

The effect on weed growth, mostly purslane (*Portulaca oleracea*), was again striking in this experiment. One pound of 2,4-D per acre suppressed the growth of weeds somewhat, while 2 pounds caused considerable reduction in growth for 1 to 2 weeks. Later the weed growth where 2 pounds were applied was as thick as on the check plots, but not as large. The 4-pound application gave good control of weeds, only a few being present, and when 8 pounds was used the plots were practically free of weeds for the duration of the experiment (5 weeks).

#### RESULTS IN 1946

In 1946 an attempt was made to find a practical method of using soil applications of 2,4-D to control weeds in sweet corn and onions. Except as pointed out later, the same preparation of 2,4-D was used as in 1945 and applications were made as a spray to the soil surface, the amount of water varying from 200 to 400 gallons per acre in the various experiments but being constant within any one. Only one planting was made in each experiment, the 2,4-D treatments being applied at intervals either before or after planting. One or more weed counts were made in each experiment, the first one 4 to 6 weeks after planting. All weeds were removed each time a count was taken. Thus, the difference in weed growth due to treatment was largely eliminated as a factor affecting yield. Except as otherwise noted all experiments were located at Madison.

The 1946 growing season was exceptionally dry and the experimental results were undoubtedly different from what they might have been in a season of higher rainfall. The total precipitation at Madison for the 5-month period from April to August inclusive was 9.75 inches compared with a normal of 17.47 inches.

Treatments were replicated four times in randomized blocks and an analysis of variance was run on all data. Wherever it seemed advisable, square root transformations were also used but in no case were the odds of significance more than slightly changed by this procedure. Therefore, only the least significant differences on the whole numbers are presented.

*Pre-Planting Treatments on Sweet Corn:*—To study the effect of soil applications on sweet corn, 2,4-D was applied to a silt loam soil having a pH of 7.5 at the rate of 4 and 8 pounds per acre, 0, 8, and 14 days before planting. The entire area was rototilled 3 to 4 inches deep just before the first treatment was applied on May 2. Immediately after a plot received a 2,4-D spray, it was rototilled to a depth of about 3 inches. The entire area was again rototilled just before planting, but this time the tiller was set to work no deeper than 1½ inches. This was to avoid bringing new weed seeds to the treated layer.

Golden Cross Bantam sweet corn was planted May 16 in plots 15 by 36 feet with hills spaced 3 feet apart each way, five kernels being planted by hand in each hill. Weed and stand counts were made 1 month after planting. The weeds present were mostly purslane (*Portulaca oleracea*). Weed counts were made by determining the number of weeds in a frame 6 inches square thrown into five parts of each plot. The five counts were added together for statistical analysis. As soon as the weed counts had been made, the entire field was hoed and cultivated to a depth of about 1½ inches. Two subsequent cultivations were made. In harvesting, only the three center rows were used in each plot and a border strip was discarded on the ends. The corn was picked as it reached canning maturity, harvests being made August 19, 26 and September 3.

The results of this experiment are shown in Table II. The number of weeds was greatly reduced by all 2,4-D applications. In general the effectiveness increased with rate of application and reduction in time interval between treating and planting.

The stand of corn was significantly reduced only by the 8 pound application applied the day of planting. However, all treatments caused a delay in emergence, the degree being in general agreement with the severity of the treatment. There was also a delay in tasselling and in maturity of the corn. The latter effect is reflected in the table by the yield of corn at the first picking. All except the mildest treatment, that is, 4 pounds of 2,4-D applied 2 weeks before planting, caused a significant reduction in the first picking. Total yield, however, was only slightly lower than the check for any of the treatments and in no case was the difference significant.

It should be pointed out that within either the 4- or 8-pound rate of application of 2,4-D, the effects on both weeds and corn decreased as the interval between treatment and planting increased. It should

TABLE II—EFFECT OF PRE-PLANTING SOIL TREATMENTS WITH 2,4-D ON WEED CONTROL AND THE STAND, EARLINESS AND YIELD OF SWEET CORN

Treatment		Average No. Weeds Per 180 Sq In	Average No Corn Plants Per Plot	Yield of Marketable Corn in Tons Per Acre	
Pounds 2,4-D Per Acre	No. Days Before Planting			First Picking	Total
0	—	138	93	3.49	4.15
4	0	10	97	2.45	3.73
4	8	60	80	2.64	3.95
4	14	61	91	3.14	3.91
8	0	4	69	1.66	3.64
8	8	10	84	2.43	3.91
8	14	54	86	2.86	4.01
Least significant difference	5 per cent level	43	16	0.52	N.S.
	1 per cent level	59	N.S.	0.72	—

also be pointed out that 4 pounds applied the day of planting gave approximately the same results with respect to weed counts, stand of corn and yield of first picking as did 8 pounds applied 8 days before planting. In other words, 2,4-D appeared to be rapidly dissipated in the soil. In this connection it was noted that even in the case of the 8 pound rate applied the day of planting, weeds started to appear by mid-summer. Although the season was generally dry, soil moisture conditions were quite good immediately after the 2,4-D applications were made, there being 1.80 inches of precipitation from May 2 to 24. This loss in toxicity of 2,4-D in warm, moist soil is in agreement with the results reported by other workers (4, 5, 7) as already pointed out.

*Pre-Planting Treatments on Onions:*—This experiment was similar to the one on sweet corn just described except that it was carried out on peat soil having a pH of 7.0 and the 2,4-D treatments were applied 1, 14 and 21 days before planting. The plots were 5 feet, 10 inches wide by 10 feet long with 14 inches between rows. The first treatment was applied April 10 and Southport Yellow Globe onions were planted with a garden seeder May 1. Tillage procedure was the same as for the sweet corn except that hand cultivators and rakes were used and the soil was worked about 2 inches deep immediately after each treatment was applied and about 1 inch in all subsequent tillage operations. The weeds present were mostly pigweed (*Amaranthus retroflexus*). Those between the rows were controlled by cultivation while the ones which remained in the row, a strip approximately 4 inches wide, were pulled from all plots by hand. Counts were made of the number of weeds in the 4-inch wide strip of the three harvest rows. Stand counts were made, and the onions harvested during the first part of September, at which time they were well matured.

The data obtained from this experiment are summarized in Table III. The stand of onions was significantly reduced by all treatments and the yield by all except the one receiving 4 pounds of 2,4-D per acre applied 21 days before planting. The average number of weeds present at the first weeding was much lower on all the plots treated with 2,4-D than on the check plots. Within the 2,4-D treatments, the



plots receiving 4 pounds 21 days before planting gave weed counts significantly higher than the other treated plots.

The number of weeds in the second and third weedings is combined in the table. All 2,4-D treatments except the one receiving 4 pounds 21 days before planting gave significantly lower weed counts than did the check. The fact that the 4 pound application 21 days before planting had nearly as high a count as the check indicates that the toxicity of the 2,4-D was wearing off. These results seem to support those discussed in connection with the sweet corn, although in this experiment the rate of loss in toxicity appeared to be slower. The latter observation may have been a result of the extremely dry weather in April. From April 10 when the first treatment was applied to May 1 when the onions were planted, there was only .25 inches of precipitation. Mitchell and Marth (7) found 2,4-D to be inactivated much more rapidly in moist soil than in air-dry soil.

It should be noted that 4 pounds of 2,4-D applied the day before planting gave practically the same results with respect to weed counts, and stand and yield of onions as did 8 pounds applied 21 days before

TABLE III—EFFECT OF PRE-PLANTING SOIL TREATMENTS WITH 2,4-D ON WEED CONTROL AND THE STAND AND YIELD OF ONIONS

Treatment		Average No. Weeds Per Plot		Average No. Onion Plants Per Plot	Yield of U. S. No. Onions (Bushels Per Acre)
Pounds 2,4-D Per Acre	No. Days Before Planting	First Weeding	Later Weedings		
0	—	479	64	261	535
4	1	33	22	140	405
4	14	16	15	155	383
4	21	63	53	185	555
8	1	17	6	68	213
8	14	13	19	60	197
8	21	22	24	136	384
Least significant difference	5 per cent level	26	24	47	106
	1 per cent level	36	33	65	145

planting. These results together with those pointed out in the sweet corn experiment indicate that a small amount applied at planting time will produce essentially the same effects as a larger amount applied at some earlier date.

*Post-Emergence Treatments on Onions:*—It was thought that established plants might be more resistant than germinating seeds to 2,4-D soil treatments. Weaver, *et al* (11) showed established soybean plants to be relatively unaffected by 2,4-D soil treatments, but 10 and 20 pounds per acre applied at planting time markedly reduced the yield. An experiment was conducted in which the 2,4-D for each plot was dissolved in water and applied to about 2.5 pounds of sand. This was then dried, mixed and spread on the soil, 1, 2 and 3 weeks after the onion plants were up to give 4 and 8 pounds of 2,4-D per acre. By this procedure, it was possible to treat the soil without getting 2,4-D on the tops. Earlier experiments (10) have shown that onion seedlings are killed by 2,4-D sprays.

The 2,4-D treatments resulted in considerable stunting and distortion of the weeds, but only about 50 per cent reduction in the num-

ber present at the time of the first weeding. All treatments greatly reduced the number of weeds at the second weeding. However, there were only about one-sixth as many present on the check plots at this time. The reduced effectiveness on early weeds as compared with pre-planting treatments may be a result not only of the delayed application, but also of the dependence on rainfall to wash the 2,4-D into the soil.

The treatments appeared to have practically no effect on the stand of onions. The yield, however, was 12 to 35 per cent lower on the treated plots and the differences were significant in all except one case. The onions looked normal on all plots early in the season, but by mid-July it was noted that many of the roots were injured by 2,4-D and all but a few roots were dead on some of the plants. This is in agreement with results reported by Allard, *et al* (1) and Nutman, *et al* (8) who found the greatest effect of soil applications of 2,4-D was on the roots.

*Pre-Emergence Treatments on Onions*.—In these experiments the 2,4-D was sprayed on the soil just before the onions emerged. The idea in this procedure was to kill by contact all susceptible weeds above ground at the time of spraying and to leave enough 2,4-D in the soil to suppress later weed growth. It was hoped that the onions might be injured less than when the 2,4-D was applied at time of planting.

A seeding of onions was made May 14 and sprays applied May 25. At time of spraying only a few scattered onions were showing above ground. The field, variety and plot size as well as weeding, cultivation and harvesting procedure was the same as that used in the pre-planting experiment. The yield was extremely low and the bulbs small due to late planting and dry weather.

The results are presented in Table IV. Both rates of application caused a large reduction in the weed population (Fig. 1) and the weeds that survived were severely stunted and distorted. It is probable that some of these weeds would not have survived had they been left undisturbed. The stand of onions was significantly reduced by the 8-pound but not by the 4-pound rate. The yield of total and No. 1 onions was reduced by both treatments, especially by the heavier quantity. An analysis of co-variance indicated that the reductions in

TABLE IV—EFFECT OF 2,4-D PRE-EMERGENCE SPRAYS ON WEED CONTROL AND THE STAND AND YIELD OF ONIONS

Pounds 2,4-D Per Acre	Average Number Weeds Per Plot		Average No. Onion Plants Per Plot	Yield of Onions (Bushels Per Acre)	
	First Weeding	Later Weedings		U. S. No. 1	Total
0	626	33	286	156	380
4	164	7	244	123	305
8	61	1	195	44	179
Least significant difference	5 per cent level	144	16	69	46
	1 per cent level	218	24	105	69

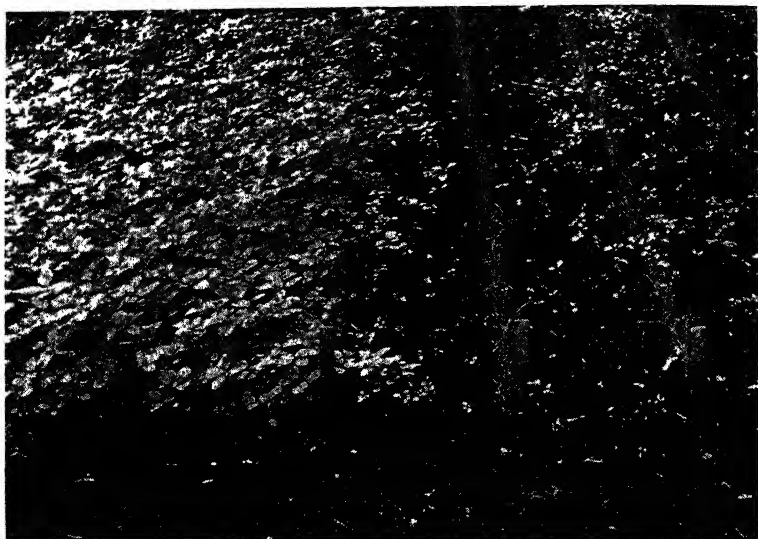


FIG. 1. Effect of a 2,4-D pre-emergence spray on weed growth in onions. Left: untreated. Right: 4 pounds of 2,4-D per acre applied just before the onions emerged.

yield are due some to differences in stand but mostly to differences in size of onions.

Late planting and dry weather may have resulted in greater injury from 2,4-D in this experiment than would have occurred under more favorable conditions. The onions showed little apparent injury early in the season, but later the roots were severely damaged on treated plots and some plants died. The 2,4-D did not seem to disappear as rapidly as when the soil was more moist which was the case in some of the other experiments.

A treatment with 2,4-D at 4 pounds per acre was included in an experiment conducted in a commercial field in Racine County under more favorable growing conditions. The 2,4-D was applied as a pre-emergence spray on May 14 just as the first onions were coming up. Accurate weed counts were not made, but the observed control was good. The average yield of onions on the untreated plots was 995 bushels per acre and on those treated with 2,4-D it was 884 bushels. The difference, however, was not significant at the 5 per cent level. The average number of onion plants per plot was 206 for the untreated and 143 for the treated, this difference being highly significant.

A third experiment with pre-emergence sprays on onions was conducted in another commercial field. In this case, in contrast to all the other experiments, a preparation was used which contained 22 per cent 2,4-D as the butyl ester in an oil emulsion. The rates of application were 4 and 8 pounds per acre and the same procedure was used as before. Only a few onions came up on any of the treated plots and

all of these died when still small. Although further study is needed, it appears that results may be greatly influenced by the 2,4-D preparation used.

*Effect of 2,4-D on Keeping Quality of Onions:*—Samples were taken at time of harvest from all experiments and placed in a rather warm room to give severe storage conditions. When removed on February 19, 1947, the average shrinkage for all lots was somewhat over 30 per cent and was due largely to sprouting. There were only slight differences in the per cent shrinkage between any of the untreated and treated lots.

#### DISCUSSION AND SUMMARY

The results of these experiments indicate that good control of fox-tail, purslane, pigweed and certain other annual weeds may be obtained by soil applications of 4 or more pounds per acre of the sodium salt of 2,4-dichlorophenoxyacetic acid. Slightly lower rates may give practical control but more information is needed on this point. The treatments seemed to effect only germinating seeds since new weeds started to grow in undisturbed soil when the toxicity of the 2,4-D had disappeared. This observation makes questionable the possibility of killing weed seeds in the soil with 2,4-D and growing weed free crops at a later date when the toxicity has disappeared as suggested by Hamner, *et al* (5) and Mitchell and Marth (7). Our experiments indicate that to be effective 2,4-D must be present in toxic concentrations at the time the weed seeds are germinating.

The time required for dissipation of the 2,4-D appeared to be influenced by both rate of application and soil moisture. In general, an increase in rate of application or a decrease in soil moisture prolonged the period of toxicity. In these experiments, 4- and 8-pound applications of 2,4-D gave good weed control for a period of 6 to 8 weeks or longer.

The germination of all crop plants tested with the exception of oats and sweet corn was reduced by 2,4-D soil treatments applied at or just before planting time. An experiment with sweet corn using pre-planting treatments indicated possible practical application on this crop since good weed control was effected with no reduction in total yield. Maturity, however, was delayed by all 2,4-D treatments. Four pounds of 2,4-D applied the day of planting and 8 pounds applied 8 days before planting had similar effects on weed control and on the stand, maturity and yield of corn.

Several experiments were conducted on onions using 4 and 8 pounds of 2,4-D per acre applied to the soil as pre-planting, pre-emergence and post-emergence treatments. With only three exceptions, the yield was significantly reduced by all treatments in all experiments. The stand of onions was significantly reduced by all the pre-planting treatments and by some of the pre-emergence treatments, but when 2,4-D applications were made to the soil after emergence there was no reduction in stand. It is possible that extremely dry weather in 1946 may have resulted in much more severe injury from 2,4-D treatments than would have occurred in a more normal season.

Excellent control of weeds was obtained when 2,4-D was worked into the soil before planting. There was no advantage in applying 8 pounds per acre 3 weeks before planting compared with 4 pounds the day before planting either in weed control or in lessened injury to the onions. Weed control was not quite as good when 2,4-D was applied as a pre-emergence spray. The post-emergence treatments gave good control of late weeds, but resulted in only about 50 per cent reduction in the number of weeds at the time of the first weeding.

In one pre-emergence experiment, a butyl ester preparation of 2,4-D was used and resulted in a 100 per cent reduction in the stand of onions. This indicates that the formulation may greatly effect the results.

Pre-planting and pre-emergence treatments with 2,4-D on onions appear to warrant further study. Post-emergence applications, on the other hand, offer little promise due to poor control of early weeds. It may be possible by increasing the rate of seeding or by using somewhat less than 4 pounds of 2,4-D per acre to obtain good control of weeds using pre-planting or pre-emergence treatments without reducing the yield. Even if this cannot be done, in exceptionally weedy fields the reduction in yield caused by 2,4-D soil treatments might be more than offset by the saving in labor.

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## Chemical Control of Weeds

By E. M. HILDEBRAND, *Texas A. & M. College,  
College Station, Tex.*

THE broader subject of herbicides was reviewed by the writer last April (27) in the special Herbicide issue of Science. In that report herbicides were divided into seven groups: 1, soil sterilants; 2, non-selective contact sprays; 3, selective sprays; 4, translocated poisons; 5, flame thrower; 6, growth regulators or hormones; and 7, miscellaneous mechanical devices and physical barriers.

The discussion today will be confined largely to recent work with chemical herbicides with emphasis on the sensational growth-regulating types of chemicals.

Weed control specialists are much interested in the mechanical devices that have been invented and used for applying the various herbicides. The application phase of the work with herbicides, illustrated in the report of Harvey (23) of California, must be omitted here for want of time. However, its importance should not be underestimated. The new Daugherty sprayer (1) mounted on a boat for combating the water hyacinth in Florida waters is an illustration of the active interest of engineers in work with herbicides. Raynor and Britton (42) studied the toxicity of several herbicides to livestock.

Until about 10 years ago there were only about two types of chemicals, soil sterilants and nonselective contact sprays, used to any extent in this country's agriculture. Hence in the intervening years a remarkable group of chemicals has been found useful for combating the weed menace.

### 2,4-D

Since the discovery of the herbicidal action of 2,4-dichlorophenoxyacetic acid or 2,4-D in 1944 (Hamner and Tukey, 19) there has been more experimental work on this remarkable substance than on all the other herbicides combined. Even the War Department conducted extensive researches, of which only three references are cited here (45, 46, 50).

Kephart (31) used the term "Revolutionary Discovery" for the 2,4-D chemical because it opened up a new and remarkable approach to weed control by growth regulation with a plant hormone. This remarkable herbicide was the principal subject of the Second Annual North Central States Weed Control Conference (3) held in St. Paul, Minnesota in late November 1945. Reports of both the Western (4, 5) and North Central (3) Conferences and by representatives thereof (Harvey, 25; Willard, 52) gave the progress of the work done with 2,4-D in 1945 for the control of numerous weeds in these sections of the country. Besides many other research reports, (6, 7, 8, 9, 13, 14, 18, 20, 21, 22, 24, 28, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 43, 44, 45, 46, 50, 63 — and others of scientific and popular interest, too numerous to mention) have been made by different individuals and groups.

Let us now consider the 2,4-D herbicide in some detail. The reports

by Harvey (25) and Willard (52) give many important details on what 2,4-D is, some of its distinctive characteristics, its hazards, its effect on the soil, methods of application, how strong a solution to use, how to make the recommended solutions with commercial materials, some general principles in the use of 2,4-D for the control of weeds in lawns, pastures, grain and cultivated fields. To guide individual users, information is given on the forms of 2,4-D available on the market, which forms to try, how to read the label and decide what to buy. Therefore, what you do should be governed accordingly.

Although the earliest work with 2,4-D was carried on in the Eastern United States (19) and in England (37), some of the most extensive experiments and tests have been conducted in California and the other western states. During 1946 much work has been in progress practically everywhere in the United States and Canada and elsewhere. Letters have been received by the writer from India and Belgium requesting information on 2,4-D and its sources. Today in all places the results are far from complete, with recommendations being constantly revised as new information becomes available.

Numerous investigators (3, 5, etc) have shown that cereal and grass crops exhibit considerable tolerance for the plant hormone type of chemical weed killer whereas most broad-leaved plants, including many weed species, are highly susceptible. Consequently, the growth regulators have been used selectively to control broad-leaved weeds in lawns, pastures, cereal crops and in other places.

In his summary on weeds studied in California, Harvey (25) lists 49 weed species susceptible and 23 species resistant to the 2,4-D herbicide. Crafts (16) gives a table listing the names of weeds whose reaction to growth regulators like 2,4-D has been recorded. The list includes 103 susceptible, 18 intermediate and 62 resistant species of weeds. Others (3, 5, 52) have prepared lists of this character for other sections of the country.

The writer (28) reported the results of successful tests conducted in Florida for the control of water hyacinth. A 0.1 per cent concentration gave good control. A considerable amount of promising work with 2,4-D has been and is now being done in the southern states infested with this and other aquatic weeds.

Crafts (14) has reported that aquatic weeds are becoming increasingly important as agricultural pests in irrigation and drainage systems as well as along rivers and in lakes and ponds in California. Both chemical and mechanical methods of control are given. He states that 2,4-D (1-1000) is proving valuable in controlling many types of weeds including the water hyacinth, water primrose, *Hydrocotyl* and other surface water weeds.

Recent unpublished work by Harvey and Crafts indicates the successful use of 2,4-D in eliminating cattails (*Typha* spp.), tules or bulrushes (*Scirpus* spp.), bur-reed (*Sparganium eurycarpum*), willows, and other weeds of wet lands and drainage channels. These investigators also indicate that growth regulators or hormones are translocated in polar fashion from foliage to roots and thereby kill the perennial root systems of many weeds. The weeds listed to illustrate the

mechanism were wild morning glory, Canada thistle, dandelion and plantain. They found the growth regulators valuable also against poison ivy, poison oak, poison sumac, Japanese honeysuckle, and similar pests in pasture and woodland areas.

The writer (29) has tested 2,4-D in experiments for the control of nutgrass (*Cyperus rotundus* L.) both in Florida and Texas. A 0.1 per cent concentration was effective for killing the aboveground parts whether in the lawn or garden. Repeating the sprays at specified intervals, on all new growth initiated at the nuts, seemed to have all but eradicated the weed after the third application. However, we must wait and see what develops next season.

Harvey (25) reported that nutgrass was susceptible to a 0.2 per cent solution of methyl ester of 2,4-D dissolved in kerosene.

The work done with 2,4-D in California (13, 14, 16, 26) touches a number of points of special interest to us here in the South. Last summer 2,4-D was applied to rice fields by means of airplanes. The application of 15 gallons of spray per acre, containing 1½ pounds of 2,4-D, was effective in controlling arrowhead lily, water plantain, some of the sedges, and other aquatic species in rice fields, with no injury to the rice. In these reports some of the other weeds receiving special mention were nutgrass (a sedge), wild blackberry, poison oak, klamath weed, Russian knapweed, hoary cress, Canada thistle and morning glory.

Van Overbeek (38) found a single application of 2,4-D was highly effective for controlling nutgrass (*Cyperus rotundus*) and day flower (*Commelina longicaulis*) in the sugar cane fields of Puerto Rico. A concentration of 0.075 per cent controlled the day flower and 0.3 per cent the nutgrass.

Brown and Carter (8) tested 2,4-D for the control of the alligator weed which has become a pest in the waterways, lakes and even on cultivated land in Louisiana and obtained promising results. In their tests 2,4-D also killed many other weeds. Brown (6) cautions against the careless use of 2,4-D because of fume injury to a number of very sensitive ornamental plants grown adjacent to lawns. Young (53) obtained almost complete kill of the tops of persimmon, sassafras and dewberry but over one-third of the stumps resprouted. The work of Brown and Ryker (7) in Louisiana indicates that 2,4-D has much promise in weed control in both sugar cane and rice fields.

Shafer *et al.* (43) have reported the results of preliminary tests on corn weeding with 2,4-D. Their results invite further study on this and other herbicides for weeding corn.

In this country the 2,4-dichlorophenoxyacetic acid compound has been most widely used whereas in England, British investigators (37, and others) working independently have discovered a weed killer which appears more selective and, in some cases, more toxic than 2,4-D. This material is 4 chloro 2 methyl phenoxyacetic acid.

Crafts (13) gives illustrations of certain popular articles and advertisements that have made exaggerated and unjust claims concerning the properties of 2,4-D. In line with the work of Hamner, *et al.* (18) he demonstrated that 2,4-D. will sterilize the soil temporarily.



However, decomposition in the soil is fairly rapid with 75 per cent of the toxicity to peas, oats and sunflowers being lost during the first month after application. These results agree with the results in England (37) that 2,4-D is effective both as a contact spray on the plant and as a soil sterilant.

In the 8th Annual Report of the Research Committee of the Western States Weed Control Conference (5) Freed gives the chemistry of the different forms of 2,4-D. Since 2,4-D is essentially insoluble in water it must be treated in order to get it into solution. This may be accomplished in two ways: (a) dissolving in a water-soluble or emulsifiable solvent, and (b) by converting it into a water-soluble salt. Some of the possible salts are sodium, potassium, ammonium, calcium, and triethanolamine. In general these salts are sufficiently soluble in water for the purposes intended.

At present there are over 60 commercial products containing 2,4-D on the market. A number of the so-called sodium salt preparations of 2,4-D are a mixture of sodium bicarbonate and 2,4-D acid which form the salt when introduced into water. Besides the sodium and ammonium salts of the acetic acid derivatives both the phenoxy and naphthoxy compounds have been effective. Organic salts, such as the triethanolamine salt are possible.

Another class of derivatives of 2,4-D that are of interest in weed control are the esters. These derivatives are the result of the reaction between the acid and an alcohol. Thus there is a possibility here for a homologous series of esters including methyl, ethyl, propyl, butyl, octyl and cyclohexyl esters. These esters are insoluble in water but are soluble in oil and in most organic solvents. Concurrently these derivatives should be more soluble in the cuticle of plants. Thus one might reasonably expect better results with the methyl ester of 2,4-D on a plant having very waxy leaves, than with the sodium salt.

There are other derivatives of 2,4-dichlorophenoxyacetic acid possible. It is possible to have a homologous series of acids ranging through acetic, butyric, and others. Varying substitutions on the benzene nucleus give rise to an infinite variety of compounds. The British discovery of 4-chloro 2-methyl phenoxyacetic acid invites further investigation on such phytotoxic derivatives of 2,4-D. A large number of growth regulators and other substances have been tried by the War Department workers (46) and others will undoubtedly be synthesized. Since most of these acids are in their parent form, each offers opportunity to form metallic salts, esters, amides, etc. Thus almost innumerable compounds can be synthesized for study and testing.

In bringing this discussion on 2,4-D to a close, attention is called to the report by Harvey (24) in California that 2,4-D was non-poisonous to animals, which is in agreement with work done in the central and eastern states (3). The remainder of this paper will deal with recent work on only a few of the more important herbicides, Sinox, Oils, Benoclor and Ammonium Sulfamate.

## SINOX

The story of Sinox and the uses to which it has been put as an herbicide were summarized in an earlier report (27). The introduction of Sinox (sodium dinitro ortho cresylate) in 1938 started a new phase in the use of selective herbicides (16). Westgate and Raynor (51) proved this material to be highly selective, noncorrosive, and far less toxic to animals than sodium arsenite. Soon after its commercial introduction Sinox was used extensively on the Pacific Coast. In Oregon, Harris and Hyslop (22) tried Sinox in combination with other chemicals, (ammonium sulfate, calcium cyanamid, sodium bisulfate, sulfuric acid, sulfamic acid, and ammonium sulfamate) to check on the addition of a fertilizer along with the herbicide. All these chemicals increased the effectiveness of Sinox, with ammonium sulfate producing the most outstanding results. Since the toxicity of Sinox was increased when these acid salts were used, their addition became known as "activation."

The first step in increasing the toxicity of the dinitro compounds was the use of salts as activators. The next step was to test the ammonium salt of dinitro ortho cresol. It proved as toxic as the activated sodium salt. Although the ammonium salt is not as highly inflammable as the dry sodium salt, it is a water-soluble dry powder that may readily be used under field conditions. Its use reduces the weight of the material required per acre from 10 pounds (1 gallon of Sinox) to 3 pounds. Lengthening the aliphatic chain of dinitro ortho cresol increases toxicity up three steps to dinitro ortho secondary butyl phenol.

Activated Sinox according to Crafts (16) controls such weeds as mustards (*Brassica nigra* and *B. arvensis*), wilt turnip (*B. campestris*), hedge mustard (*Sisymbrium* sp.), fiddleneck (*Amsinckea* sp.), fan weed (*Thlaspi arvense*), pennycress (*T. perfoliatum*), Russian thistle (*Salsola kali*), prickly lettuce (*Lactuca scariola*), corn cockle (*Agrostemma githago*), shepherd's purse (*Capsella bursa pastoris*), small nettle (*Urtica urens*), nightshade (*Solanum nigrum*), wild buckwheat (*Polygonum convolvulus*), lambsquarter (*Chenopodium album*), and hungerweed (*Ranunculus arvensis*) in the crops of wheat, barley, oats, rye, flax, peas, corn, onions, garlic, ryegrass, and fescue.

A special Sinox No. 1 preparation and a Dow Selective Herbicide were tested by Harvey and Riddle (26) for controlling alfalfa weeds in California. Although limited these tests indicate that these chemicals kill almost 100 per cent of the weeds except for the older knotweed plants. Sinox has been tested by Warren (48) and others. In his tests (48) Sinox and G-506 worked well only on peas among the vegetable crops studied.

## OILS

Discovery of the selective action of certain petroleum fractions added the group of crops, called the Umbelliferae, to the list that may be weeded by means of chemicals — carrots, celery, parsnip, parsley, dill, and caraway. Also the guayule plant will tolerate stove oil and low dosages of diesel oil. Certain oils in undiluted form effect the selective killing of certain plant species from mixed plant populations. Its ac-

tion seems to depend on the chemical tolerance of certain plants to certain toxic substances, which effects depend on factors that can be regulated — composition of the herbicidal material and stage of growth of plants.

Warren (47), working on a number of different herbicides, reported recently on his results with oils in 1945 and outlined the scope of the weeding of common vegetable crops with chemicals. He states that the best selective weed spray for a vegetable crop at present is the use of oil for carrots. The oil he found reliable was Stoddard Solvent, a product that contains the right percentage of toxic aromatics to kill weeds without injury to carrots. Details were given on costs and equipment for its application. Other chemicals — Sinox, dilute sulfuric acid, and 2,4-D — are also discussed. Unfortunately, both Sinox and 2,4-D kill most common vegetable crops and therefore cannot be used extensively as selective sprays on most vegetables.

Warren and Hanning (49), Lachman (32), Crafts (15), Crafts and Reiber (17), and others have done extensive work indicating that Stoddard Solvent and a few other oils with the proper aromatic content (about 15 per cent) are valuable weed killers especially in carrot fields. According to Lachman (32) there are several other resistant vegetable plants in seedling stages besides those already mentioned — fennel, coriander, parsnip-rooted parsley and celeriac.

Crafts and Reiber (17) go into considerable detail on the herbicidal properties of oils involving their use both as selective and nonselective herbicides. Their results with selective oils on vegetables invite study by investigators in other sections of the country under different climatic conditions.

Crafts (14) employed a number of different chemicals for combating aquatic weeds in California. Some of the sprays that gave control of the prevailing types of aquatic weeds were diesel oil, dilute solutions (2-4 per cent) of sodium chlorate, 5 per cent ammonium sulfamate, 4 per cent Dow Contact Herbicide (dinitro secondary butyl phenol in self-emulsifying oil), and Benoclor (a chlorinated benzene with emulsifiers).

#### BENOCOLOR

Benoclor (14) is considered by some as the greatest single development in control of aquatic plants by chemical means. Benoclor is a heavy liquid that readily disperses in water to form a milky suspension. When sprayed through nozzles below the water surface into a flowing stream it will make the total mass of liquid into a stable milky emulsion. When it comes into contact with aquatic weed growth, it is absorbed by the plants and they are injured or killed. By means of a simple powered pump and nozzle system, irrigation ditches may be treated as the water flows past a station. Static water in a ditch may be treated by moving the pump. The pump can be mounted in a boat to treat aquatic plants in lakes. Water fauna are killed in treated ditches. By carefully treating narrow strips of vegetation in lakes, injury to fish can be minimized. This chemical is not considered injurious to wildlife or stock. Applications are made after the growth in spring and early summer begins to cut the flow of water. The action

of the chemical is rapid and normal carrying capacity of a ditch can be restored within 24 hours. Exposure to a concentration of 500 ppm (by weight) for 1 hour kills weeds. Benoclor is being used in eastern states for controlling aquatic weeds in ponds and along lake shores. No doubt some work has been done with it in the South.

Before concluding these remarks brief mention should be made of the work on herbicides by Young (53) in East Texas. Although the work is preliminary in nature some degree of control of persimmon and sassafras sprouts and of stinging nettle was obtained. Ammate (ammonium sulfamate) killed nearly all stinging nettles in one application at a concentration of 1 pound to 1 gallon. 2,4-D killed tops of persimmon, sassafras, and dewberry but prevented resprouting of less than two-thirds of the stumps. Dow Contact Herbicide killed the tops of persimmon, sassafras, and dewberry. However, these plants produced new growth and the grasses and sedges also reappeared within a few months.

#### DISCUSSION

Eight years ago the Western Weed Control Conference was organized. In doing so the weed control specialists of 11 western states discarded the time-worn apathetic attitude toward the problem of weed control and started a program of action. Their organized action came just after the appearance of new herbicides on the market such as Sinox and oils. Most farmers and most specialists probably were justified in their attitude that nothing much could be done about the pesky weeds until the appearance of the new herbicides, a development that has been confined to only the past decade.

Recently the United States Chamber of Commerce published the results of a survey which revealed that weeds cause the farmers and gardeners of the United States an annual loss of \$3,000,000,000.00. Has anyone reminded us that this loss from weeds is probably as great, if not greater, than the loss to farmers from all livestock diseases, insect pests and plant diseases combined?

In November 1944 a North Central States Weed Control Conference was organized consisting of 13 states. This conference came into being just after the revolutionary discovery of the new weed killer 2,4-D (19). Their second annual conference report at St. Paul, Minnesota, was largely devoted to a discussion of 2,4-D and other new herbicides. At their third annual conference held in Des Moines, Iowa, in December 1946 the name of the conference was changed to the North Central Weed Control Conference so as to include the adjoining provinces of Canada. Attending the conference were representatives from the East who are now planning to meet in February 1947 with the idea of starting an Eastern States conference. Because weeds seem to be even more severe in the South than elsewhere in the country it would seem that those of us interested in weed control in the southern states should also be stirred to organized action.

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## Propagation of Bamboo by Branch Cuttings

By DAVID G. WHITE, *Federal Experiment Station, U. S.  
Department of Agriculture, Mayaguez, Puerto Rico*

THE bamboos are perennial grasses in which flowering and seeding generally occur at intervals ranging to 80 years or more (1). Therefore, the most common method of propagating clump bamboos is by divisions. This method has the disadvantage of being costly, particularly with those species which develop large culms. The removal of divisions also disrupts the parent clump which might otherwise produce new culms for many years. Divisions of certain species may weigh 15 to 30 pounds each with the result that transportation problems limit distribution.

The above disadvantages of propagating by divisions can be overcome in some instances by using cuttings. Different types of cuttings may be obtained from bamboo culms but there is considerable variation in rooting among species. For example, green culm sections 2 to 4 feet in length of *Bambusa vulgaris* Schrad. ex Wendl., which is not industrially important, often root in moist soil. Culm sections of most other species, however, show little or no indication of rooting and soon die. Cobin (2) at the suggestion of McClure<sup>1</sup> had some success in rooting cuttings made from the basal parts of lateral branches.

Each lateral branch has an enlarged region at its point of origin on the culm. This enlargement is composed of a series of extremely short internodes separated by nodes which sometimes possess the ability to produce roots. In fact, small root initials develop naturally from these nodes in some species (Fig. 1). In this study each branch was removed as closely as possible to the culm with a hacksaw. At the opposite end, the tip of the branch was cut off 12 to 18 inches from the enlarged base. An experiment was designed to test each of the following economic species of clump bamboos: 1, *Bambusa longispiculata* Gamble ex Brandis; 2, *B. polymorpha* Munro; 3, *B. textilis* McClure; 4, *B. tulda* Roxb.; 5, *B. tuldoidea* Munro; 6, *Cephalostachyum pergracile* Munro; 7, *Dendrocalamus asper* (Schultes) Backer; 8, *Gigantochloa apus* (Roem. & Schult.) Kurz ex Munro; and 9, *Sinocalamus oldhami* (Munro) McClure.

Cuttings were obtained from 2-year culms at 3-month intervals over a period of 1 year. Fifty cuttings of each species were taken on each date and divided into groups for treatment with root-promoting substances. The alcohol-dip method of treatment employed by Cooper (3) was used. The basal portions of 10 cuttings of each species were dipped for 5 seconds in one of the following solutions: (a) 5 milligrams of indole-3-acetic acid; (b) 2 milligrams of indole-3-butyric acid; (c) 2 milligrams of alpha naphthylacetamide; and (d) 0.1 milligram of 2,4-dichlorophenoxyacetic acid per milliliter of alcohol. In

<sup>1</sup>F. A. McClure, Field Service Consultant on Bamboo, Complementary Crops Division, Office of Foreign Agricultural Relations, United States Department of Agriculture, Washington, D. C.

addition, 10 cuttings for controls were not treated. Immediately after treatment the cuttings were planted in moist sand within a greenhouse, except those obtained in December which were planted outside in sand beneath partial shade. Observations of rooting were made 2 months after each planting.

No differences in rooting were found which could be associated with the root-promoting treatments. Therefore, the data from 50 cuttings of each species obtained at each date were summarized as units for comparison of differences among species and the time of year they were obtained. These data are presented in Table I. Considerable variation in rooting occurred among the species. Although no cuttings of *Bambusa tuldooides* and *Cephalostachyum pergracile* rooted in any trial, about half of those of *Gigantochloa verticillata* rooted except in September. *Simocalamus oldhami* was the only species in which at least some cuttings rooted in all the trials. September was a poor month

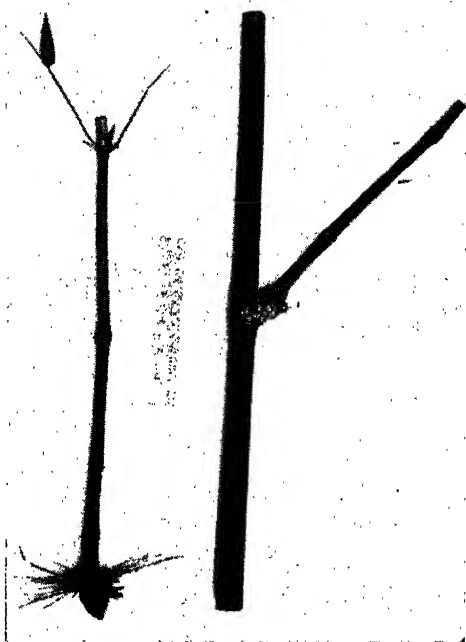


FIG. 1. At the right is a culm section of *Dendrocalamus asper* with a lateral branch suitable for use as a cutting. Note the enlarged region at the base of the branch and the small root initials arising from the nodes. At the left is a rooted branch cutting of the same species 2 months after planting.

TABLE I.—THE ROOTING OF SEVERAL SPECIES OF BAMBOO BRANCH CUTTINGS IN RELATION TO THE MONTH THEY WERE OBTAINED (50 CUTTINGS OF EACH SPECIES USED EACH DATE)

Species	Per Cent Cuttings Rooted In—				Average (Per Cent)
	March	June	September	December	
<i>B. longispiculata</i> .....	2	0	0	0	0.5
<i>B. polymorpha</i> .....	0	0	0	12	3.0
<i>B. textilis</i> .....	16	24	2	0	10.5
<i>B. tulda</i> .....	2	0	0	12	3.5
<i>B. tuldooides</i> .....	0	0	0	0	0
<i>C. pergracile</i> .....	0	0	0	0	0
<i>D. asper</i> .....	20	0	20	52	23.0
<i>G. verticillata</i> .....	50	46	0	50	36.5
<i>S. oldhami</i> .....	36	24	8	16	21.0



for rooting all species. With the exception of *B. textilis*, December or March were the best months for rooting in this experiment.

Comparison of rainfall in the month previous to obtaining the cuttings and their rooting is of interest. For example, in the November preceding the December cuttings, there was 4.51 inches of rain. In the February preceding the March cuttings, there was 3.18 inches of rain. In both instances the amount of rainfall was below the annual average of 5.97 inches per month and, in general, rooting of these cuttings was superior. However, in the May preceding the June cuttings, there was 6.04 inches of rain and these cuttings did not root so well as those taken in December or March. In the August preceding the September cuttings, there was 9.48 inches of rain and these cuttings were poorest in rooting. Thus, the rooting of bamboo branch cuttings appears to be associated with rainfall during the month previous to obtaining the cuttings.

The results of this experiment on the rooting of bamboo branch cuttings indicate that: (a) Treatment with root-promoting substances at the usual concentrations has no effect; (b) considerable variation in rooting exists among species; (c) rooting varies with the month cuttings are obtained; (d) the best month for rooting cuttings varies with the species; and (e) rooting may be associated with rainfall during the month previous to obtaining the cuttings.

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## Delayed Action of 2,4-D on Trees, Shrubs, and Perennials

By A. M. S. PRIDHAM, *Cornell University, Ithaca, N. Y.*

**D**IRECT injury and often death of above ground portions of woody plants has been reported by Hamner and Tukey (5), Marth and Kephart (6), Beatty and Jones (2), Brown and Carter (3) and Pridham (8). Few deciduous plants appear immune to injury. Narrow-leaf evergreens are not affected except for young growth in late spring or early summer. Deciduous plants respond less in late summer than in spring.

Continued injury in the season following application was illustrated by Brown (3) for Primrose, Jasmine and Tung. Pirone (7) reported similar damage to pin oak, *Quercus palustris*, and to red oak, *Quercus borealis maxima*. Injury was restricted to specific branches and not general throughout the tree. The present report concerns plants sprayed in the fall of 1945 with the sodium salt of 2,4-D. In the spring of 1946 many of these plants failed to come into growth promptly. Delayed bud break was followed by production of distorted foliage showing in varying degrees, excessive serration especially at the leaf apex. Exaggeration of the length/width ratio hence filiform leaves were common. A characteristic prominence of the veins and apparent thickening of the leaf accompanied by a "celery-like crispness". Distortion was found to vary widely in intensity and completeness of symptom. Such malformation detracts from ornamental value and renders nursery stock unsalable. Spring growth was often so reduced in length that the foliage formed a rosette and dwarfed shoot growth. This occurred in varying degrees on any one plant.

The abnormalities associated with delayed 2,4-D action differ from the usual pattern of epinasty, discoloration and death occurring as a result of direct spray injury to growing foliage in spring or summer.

Delayed action is more nearly analogous to that induced by soil treatment or seed treatment. Allard (1) illustrates these effects in red kidney bean through germination and early growth, indicating a correlation between amount of 2,4-D and the response. Hamner and Tukey (5) state that while germination was almost completely inhibited when beans were soaked in solutions of 100 ppm concentration, bean plants which grew showed virus-like symptoms. Preliminary tests with red kidney bean seed soaked for 3 hours over a range of concentrations from less than  $1/1000$  ppm to 1000 ppm gave similar virus-like symptoms. The intensity of the virus-like symptoms roughly parallels the concentration of the bathing solution. It is severe when that solution exceeds 10 ppm. Mature foliage exhibits the crisp texture of the juvenile foliage and also changes in shape to filiform.

In woody plants symptoms of delayed action of 2,4-D parallel those of red kidney beans both in range between plants and on any one branch the effect being most intense near the growing point.

When a second period of growth occurs in late summer the new foliage is often free of the earlier deformities. Herbaceous plants may display similar response both slight initial symptoms as well as marked virus-like symptoms the following season.

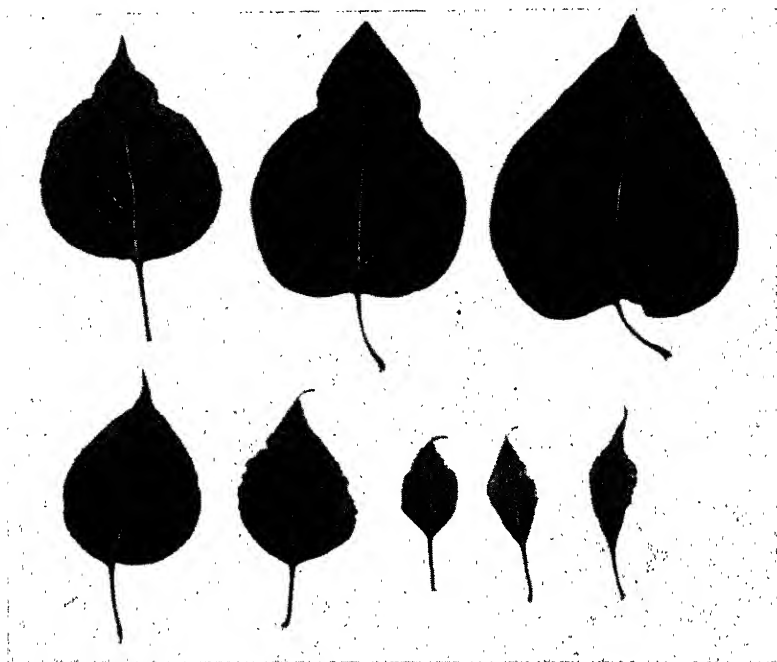


FIG. 1. Delayed action to 2,4-D in common lilac ranges from thickening of leaf and beginning of asymmetry (top row), through abnormal veination and dwarfing to extreme distortion, discoloration (bottom row). Death of foliage and twigs often follow. Delayed bud break in spring and localized response are characteristic. Abnormal growth is often followed by apparently normal growth in late summer.

TABLE I—REACTION OF WOODY PLANTS 1946 FOLLOWING A SPRAY APPLICATION OF 2,4-D, 1945

Treated	Plant	Response	
		1945	1946
September 1945	<i>Abies balsamea</i>	No	No
	<i>Fraxinus americana</i>	No	No
	<i>Larix laricina</i>	No	No
	<i>Lonicera tatarica</i>	Defoliated	Filiform leaf
	<i>Phytolacca americana</i>	Defoliated	Severe action
	<i>Polygonum cuspidatum</i>	Slight epinasty	No
	<i>Robinia Pseudo Acacia</i> (young)	No	No
	<i>Rhus Toxicodendron</i>	Killed	No
	<i>Rhus typhina</i>	Defoliated	Filiform, texture
	<i>Rubus allegheniensis</i>	Defoliated	No
	<i>Syringa vulgaris</i>	No	No
	<i>Thuja occidentalis</i>	No	Filiform, texture
	<i>Lonicera tatarica</i>	No	No
March 1946	<i>Malus Sargentii</i>	No	No

Normal response can be induced from vaporization of 2,4-D even from such dilute solutions as 1 ppm. Beans, zinnia, coleus and other 2,4-D sensitive plants confined under bell jars for 7 days have been

found to respond to methyl ester of 2,4-D; also to amine salt. Response is general throughout the plant.

The remarkably localized effect of delayed 2,4-D action suggests that it is probably associated with direct contact with 2,4-D spray rather than vapor. Failure to obtain symptoms of 2,4-D injury from spraying dormant twigs in winter suggests that absorption through the leaf or other succulent tissue of the stem is necessary.

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## Effect of Season on Responses of Snapdragons to Topping

By J. R. KAMP and S. W. HALL, *University of Illinois, Urbana, Ill.*

AN earlier experiment in height of topping of snapdragons (1) indicated that plants topped just above the fifth node produced more flower stems than those topped just above the third node. The higher topped plants had slightly shorter stems but not importantly so, and the inflorescence lengths were not unlike those from plants topped at the third node. The most remarkable difference, however, was in the time of flower production. Those plants topped high produced the bulk of their flowers in a heavy early crop, whereas those plants topped lower produced a later crop over a longer period of time. This indicated that high topping might be advisable for the market grower who was interested in cutting a crop quickly and clearing his benches for another planting. Lower topping might be best for the retail-grower who would prefer flowers to be produced at a moderate rate over a longer period of time.

The planting upon which these conclusions were based was made for a fall and early winter crop of blooms. A later planting, coming into crop after the article (1) had been published, failed to respond in a similar way.

In order to see whether the time of planting was responsible for the late crop's failure to respond to topping, the experiment was repeated in the 1946-47 season at three planting dates, giving an early, an intermediate, and a late crop of blooms. Several varieties were used in each planting but only two of them, Ethel and Junglewood White, were represented in all three plantings. In all cases, the other varieties followed the trend of the two varieties reported on but, for simplicity of presentation, only the results on Ethel and Junglewood White will be given.

At each planting, three plots of each variety were topped just above the third node, and three plots just above the fifth node. The plots were planted in triplicate to avoid any error due to position on the bench. Dates of planting seed, benching plants and topping, as well as first and last dates of cutting bloom spikes are given in Table I.

TABLE I—DATES OF HANDLING SNAPDRAGONS IN TOPPING EXPERIMENT  
1946-47 SEASON

	Seed Sown	Plants Benched	Plants Topped	First Cut	Last Cut
First planting	Jun 29, 1946	Aug 19 1946	Aug 23, 1946	Oct 15, 1946	Feb. 1, 1947
Second planting	Aug 21, 1946	Oct 21, 1946	Oct 23, 1946	Feb 8, 1947	May 9, 1947
Third planting	Oct 30, 1946	Feb 1, 1947	Feb 3, 1947	Apr 19, 1947	Jun 13, 1947

The final cutting dates were determined when plants were in such condition that a commercial man would no longer give them space on the bench. It is true that some few flowers would still have been produced, but the bench space occupied was more valuable for other purposes.

Fig. 1 presents the number of flower stems cut per 100 plants of the variety Ethel on a weekly cumulative basis. Fig. 2 presents similar data for the variety Junglewood White.

Figs. 1 and 2 plainly show the early cropping effect reported previously was again encountered in the early planting. That such an effect can be counted upon only from an early planting is also clearly

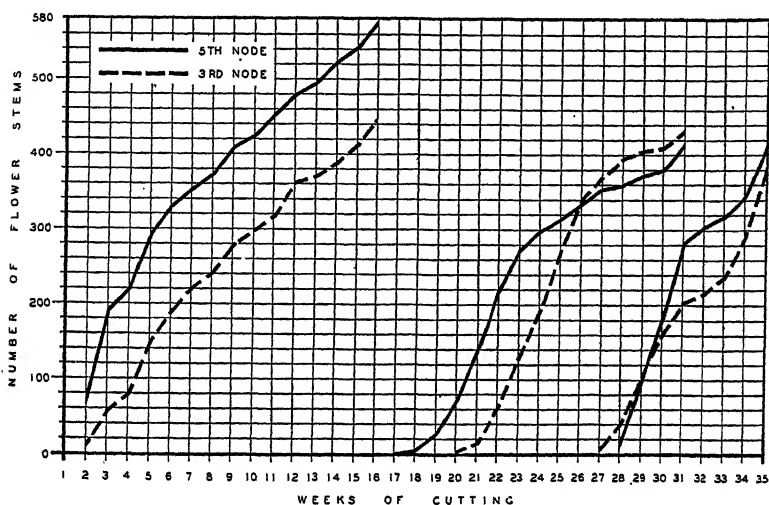


FIG. 1. Cumulative weekly total of number of flower stems cut from 100 plants of snapdragons Ethel for three successive plantings.

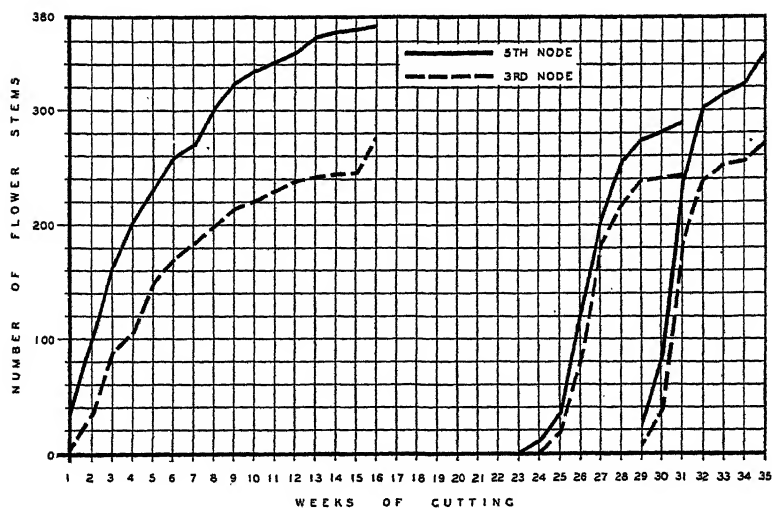


FIG. 2. Cumulative weekly total of number of flower stems cut from 100 plants of snapdragon Ethel for three successive plantings.

evident, although Ethel still showed a slight early cropping in the second planting.

Table II presents summary information concerning stem lengths, inflorescence lengths, and so on for the variety Ethel. Similar infor-

TABLE II—FLOWER PRODUCTION FROM SNAPDRAGON ETHEL  
FOR 1946-47 SEASON

	Topped	1st Planting	2nd Planting	3rd Planting
Average number of flower stems per plant. . . .	3rd node 5th node	4.49 5.79	4.35 4.17	3.86 4.15
Average stem length (inches) . . . . .	3rd node 5th node	33.32 31.96	36.27 35.05	23.96 24.01
Average inflorescence length (inches) . . . . .	3rd node 5th node	6.26 6.28	7.28 7.00	6.81 6.36

mation for the variety Junglewood White is presented in Table III.

A study of Tables II and III reveals that, in the early planting, high topping produced more, but slightly shorter, flower stems with no change in inflorescence lengths. It will be noted that in all three plantings, inflorescence lengths were not materially influenced by height of topping.

TABLE III—FLOWER PRODUCTION FROM SNAPDRAGON JUNGLEWOOD WHITE  
FOR 1946-47 SEASON

	Topped	1st Planting	2nd Planting	3rd Planting
Average number of flower stems per plant. . . .	3rd node 5th node	2.79 3.89	2.44 2.90	2.72 3.51
Average stem length (inches) . . . . .	3rd node 5th node	38.53 36.21	57.81 58.06	32.11 30.28
Average inflorescence length (inches) . . . . .	3rd node 5th node	8.71 8.00	10.10 9.87	6.90 6.56

In the second planting, the number of flower stems cut from high and low topped plants was essentially the same, as were also the average stem and inflorescence lengths.

As in the second planting, height of topping in the third planting influenced yield of stems by less than one stem per plant, and stem and inflorescence lengths by less than one inch per stem. The influence of topping was therefore seen to be confined largely to that planting designed to produce a fall and early winter crop of flowers.

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## Flower Bud Initiation and Flower Opening in the Camellia

By JAMES BONNER, *California Institute of Technology,  
Pasadena, Calif.*

IN the course of the past three years a comprehensive series of experiments have been carried out results of which have given a clear definition of certain of the factors which regulate the flowering of the Camellia (*Camellia japonica*). The application of this knowledge has made it possible to produce *Camellia* blooms, which normally appear only in fall and winter, at all seasons of the year. A summary of the information obtained is presented below not only because of its intrinsic scientific interest but also because of its possible application in the forcing of *Camellia* blooms or in plant breeding programs involving the Camellia.

The flowering of the Camellia may be divided into two phases, (a) the initiation and growth of the flower bud, which normally occurs during the summer months, and (b) the opening of the bud with the production of the flower, a process which takes place earlier or later in the fall and winter, the exact time depending on the variety. In the discussion below, these two phases of flowering will be taken up separately.

### INFLUENCE OF TEMPERATURE ON BUD INITIATION

The initiation of flower buds takes place, under otherwise favorable circumstances, only under relatively high temperatures. This is shown by the following experiment, the results of which are summarized in Table I. Twenty-five 3-year-old Camellia plants, variety

TABLE I.—EFFECT OF TEMPERATURE ON FLOWER BUD INITIATION IN CAMELLIA JAPONICA,—VARIETY, PINK PERFECTION (PLANTS MOVED TO TEMPERATURES NOTED ON MAY 25, 1946, HARVESTED SEPTEMBER 15, 1946)

Day Temperature (Degrees F)	Night Temperature (Degrees F)	No. Buds Per Plant	Fresh Wt. of Buds Per Plant (Grams)	Fresh Wt. Per Bud (Grams)
80	80°F	16.0	2.7	0.17
80-100*	65*	13.0	2.6	0.20
80	60	7.2	1.6	0.22
80	50	0.0	0.0	0.00
65	50	0.0	0.0	0.00

\*Approximate temperatures in ordinary greenhouse.

Pink Perfection (growing in soil in gallon cans), were removed from the outdoors and distributed in lots of five among five different temperature conditions. Four of the conditions were maintained in the air-conditioned greenhouse and included an 8-hour day at 80 degrees F combined with a 16-hour period at 80, 60, or 50 degrees F. In addition a 65 degree F day combined with a 50 degree F night period was included. The fifth set was placed in an ordinary greenhouse where day temperatures of 80 to 100 degrees F were combined with a nightly minimum of 65 degrees F. The plants were maintained under the



conditions noted and counts of the visible flower buds made at periodic intervals. After 3 months and 20 days all flower buds were removed and weighed. Table I gives the final count on number of buds and on their weights. It is evident that plants kept at a day temperature of 80 degrees or higher, and at a night temperature of 60 degrees or higher, produced flower buds while those at lower temperatures did not. From a quantitative standpoint also, the plants maintained at an 80 degree day temperature and a 60 degree night temperature produced less than half as many buds as those kept at 80 degrees day and night. Night temperatures below 60 degrees are therefore very unfavorable to flower bud formation in this variety of *Camellia*, and for best flower bud initiation, night temperatures at least as high as 80 degrees are required. From the standpoint of bud size, as determined by fresh weight, the individual buds did not vary greatly from treatment to treatment.

That night temperatures of 60 degrees or higher are required for flower bud formation has been found to hold true also for further *Camellia* varieties including Eureka, Daikagura, Covina, and Purity in experiments involving a total of approximately 175 plants. Failure of flower buds to set under conditions of low night temperature would appear therefore to be a general response of the *Camellia*.

#### INFLUENCE OF TEMPERATURE ON FLOWER OPENING

When *Camellia* plants are maintained under conditions of high temperature, as 80 degrees day and night, flower buds may be formed in abundance. These buds do not however open and result in normal flowers. On the contrary, the buds ultimately absciss, in general long before opening. When plants bearing flower buds are moved to lower temperature conditions the buds open and produce flowers, the length of time required for flower production depending on the temperature. The results of one experiment showing these relations are given in Table II. For this experiment 30 *Camellia* plants, variety Pink Perfection, 3-years old and in gallon cans, were taken from a commercial nursery on September 25, 1945. The plants had spent the summer out-of-doors (although in dense shade) and had formed an average of five to six flower buds per plant. The plants were divided into six lots of five plants each and placed in the greenhouse under the conditions noted in Table II. The time of appearance of each flower was recorded as well as the general character of the flowers produced in each treatment. The plants maintained at a temperature of 80 degrees day and night showed much bud drop and the few flowers which did open were greatly delayed and were in addition small, with white rather than the normal pink petals and possessed greenish centers. The most rapid flower opening resulted under conditions of an 80 degree day combined with a 60 degree night, the first flower opening 50 days after initiation of the treatment. These flowers also were somewhat smaller than those produced outdoors and were likewise paler in color. Plants in an 80 degree day temperature combined with a 50 degree night temperature produced their first flower after 95 days and these flow-

TABLE II—EFFECT OF TEMPERATURE ON THE OPENING OF FLOWER BUDS IN CAMELLIA VARIETY PINK PERFECTION (PLANTS PLACED UNDER CONTROLLED TEMPERATURES SEPTEMBER 25, 1945)

Day Temperature (Degrees F)	Night Temperature (Degrees F)	Days From Sep 25, to		Total Normal Flowers Per Plant	Character of Flowers
		1st Flower	One Half of Total Flowers		
80	80	80	155	0.0	Very small, green, 1.6 flowers per plant
75*	65*	65	90	4.8	Normal size, light color
80	60	50	90	5.8	Small, light color
80	50	95	155	5.8	Normal size
65	60	100	145	2.4†	Average larger than normal, dark pink
65	50	95	170	2.8†	Average larger than normal, dark pink

\*Approximate temperatures in ordinary greenhouse.

†Some buds not open after 190 days when experiment was discontinued.

ers were normal in size and color. Day temperatures of 65 degrees combined with night temperatures of 60 degrees or 50 degrees resulted in flowers after 95 to 100 days but the flowers were of large size and well pigmented.

The effects of temperature on flower opening in the Camellia can be summarized as follows. At high temperatures flower opening is hastened and at low temperature delayed. At the higher temperatures this effect is masked by a greatly increased bud drop. At higher temperatures the flowers produced are small and little pigmented, at lower temperatures the flowers are larger and of deeper pigmentation. In general a temperature of 65 degrees during the day combined with a night temperature of 60 degrees would appear to provide a satisfactory compromise temperature for Camellia flowering, yielding flowers of good quality without undue delay in flower opening. Somewhat higher temperatures could be used to accelerate flower opening without great sacrifice in flower quality.

The results presented above obtain not only with the variety Pink Perfection but also with the varieties Covina and Donkleri, both of which are medium to late bloomers under nursery conditions. With the varieties Daikagura and Albatross, normally early bloomers, the optimum temperature for flowering may be somewhat higher than with the later varieties. Thus, flowers produced under conditions of an 80 degree day combined with a 60 degree night appear normal in size and pigmentation while flowers produced at higher temperatures tend to be small as with the later varieties. With Purity, a medium late flower, only occasional aberrant flowers are produced with night temperatures of 70 degrees or above, while normal flowers are produced under the 65 degree day, 60 degree night regime. Although further work is needed to critically establish the optimum temperatures for each variety, still in summary, no variety thus far investigated has produced normal flowers under a continuous temperature of 80 degrees, while every variety has flowered satisfactorily in a 65 degree day, 60 degree night condition.

has not been investigated with other varieties still it would seem necessary to consider the photoperiod factor in relation to attempts to induce flower bud formation on Camellia during the winter months.

The results of Table VI indicate qualitatively that bud drop is increased under long day conditions both in Pink Perfection and in Donkleri. Flower opening was also appreciably delayed with Pink Perfection under the 20-hour photoperiods as compared to 8-hour

TABLE VI—EFFECT OF PHOTOPERIOD ON OPENING OF CAMELLIA FLOWERS  
(ALL PLANTS MAINTAINED AT A DAY TEMPERATURE OF 70 TO 80 DEGREES AND A MINIMUM NIGHT TEMPERATURE OF 65 DEGREES F)

Variety	Day Length (Hours)	No. Plants	Date Start of Treatment	No. Days to First Flower	No. Days to 50 Per Cent of Flowers	Total Flowers Per Plant
Pink Perfection	20	5	Sep 25, 1945	90	110	2.2
	8	5	Sep 25, 1945	65	90	4.8
Donkleri.....	20	2	Nov 5, 1946	—	—	Buds dropped
	8	2	Nov 5, 1946	95	115	3.0

photoperiods. Here again it would appear to be of importance to consider the quantitative influence which photoperiod may exert in determining the rate of flower production as well as total number of flowers produced per plant.

#### INTERACTION OF LIGHT INTENSITY, FERTILITY LEVEL AND WATER STRESS AS FACTORS IN FLORAL INITIATION

It has long been known to Camellia growers that bud formation on plants under nursery conditions is decreased under conditions of low light intensity. Less complete agreement has been reached on the importance of soil fertility and irrigation practice as factors influencing flower bud set. To investigate these factors as well as their interaction a factorial experiment was carried out in which three levels each of light intensity, fertility, and water stress were combined in all possible ways. To this end 216 3-year-old Camellia plants variety Pink Perfection and growing in a peat leaf mold soil mixture contained in gallon cans were distributed between the 27 treatments. Each treatment was carried out on eight plants which were divided into two plots of four plants each, the entire experiment being set up in randomized block design in a greenhouse maintained at a minimum night temperature of 70 degrees with day temperatures of 80 to 100 degrees. Three light intensities were used, the highest consisting of full greenhouse light, or approximately two thirds of full sunlight. For the other two treatments, the light intensity was decreased to one-half or one-fourth of full greenhouse light by shading the plants with cheesecloth or muslin. The three fertility levels were attained by supplying a complete 5-10-5 fertilizer at the rate of 0, 30, or 90 grams per plant. The marked growth responses to the fertilizer treatments which were evident indicated that the plants as obtained from the nursery had appreciably depleted the soil in which they were growing. The three levels of water stress were obtained as follows. In one treat-

ment the plants were watered each day or on alternate days to keep the soil at or near field capacity. In a second treatment, the plants were watered only when incipient wilting was evident, in general each 4 to 8 days depending on the light intensity. The soil was then brought back to field capacity. In the third treatment the plants were watered twice as often as in the second treatment or every 2 to 4 days. The results of this experiment are given in Table VII. They show that

TABLE VII—INTERACTION OF LIGHT INTENSITY, FERTILITY LEVEL AND WATER STRESS AS FACTORS INFLUENCING FLOWER BUD SET IN *CAMELLIA*, VARIETY PINK PERFECTION (EXPERIMENT OF MAY 25 TO SEPTEMBER 15, 1946)

Light Intensity	Number of Flower Buds Set Per Plant								
	High Fertility Level Water Level			Moderate Fertility Level Water Level			Low Fertility Level Water Level		
	High	Moderate	Low	High	Moderate	Low	High	Moderate	Low
High.....	15.7	13.0	13.7	12.1	13.6	14.7	9.3	9.9	9.5
Moderate.....	11.1	10.4	11.0	8.7	6.1	7.5	7.7	7.4	6.0
Low.....	7.4	8.7	5.9	6.7	6.2	6.9	6.1	6.1	3.9

under all conditions of fertility and water stress, light intensity is a major factor influencing the number of buds set, decrease of light intensity to one fourth of full greenhouse light being attended in every case by decrease in number of buds set to one-half or less of the number set in full greenhouse light. Increasing soil fertility, as brought about by the addition of fertilizer, brought about an increase of from 9.3 to 15.7 buds per plant at the highest light level but resulted only in an increase of from 6.1 to 7.4 buds per plant at the lowest level of light intensity where this factor was apparently the limiting one. In any case, the higher fertility levels did not result in any decrease of bud set under any condition. The influence of water stress was less clearly marked, only relatively small decreases in bud set being occasioned even by the most severe degree of water stress used. The data of Table VII indicate then that light intensity is an important factor regulating number of flower buds set per plant under temperature conditions favorable to this process. Flower bud set is also favorably influenced by high soil fertility, but is relatively insensitive to the water status of the plant. Flower bud size, as determined by fresh weight of the excised buds, appeared to be relatively independent of all of the factors tried.

## DISCUSSION

The environmental factor primarily effective in bringing about the normal cycle of flower bud formation and flower opening would appear to be temperature. High temperatures as obtain in summer are essential to flower bud formation; lower temperatures as obtain in fall and winter are essential to normal flower opening. This temperature controlled cycle would appear to be possibly reinforced also

by the influence of photoperiod, long photoperiods such as obtain in summer promoting bud set, short photoperiods such as obtain in winter promoting flower opening. The effects of photoperiod are however less striking than those of temperature and in general were of a quantitative rather than a qualitative nature.

It should be stressed that the investigations reported above do not bear on the conditions favoring vegetative growth of the plant. High light intensity in particular, which favors high flower bud set is generally known to be unfavorable to rapid vegetative growth of the Camellia, while the low temperatures favorable to flower opening are also markedly unfavorable to vegetative growth. A consideration of the interaction of factors as they relate to vegetative growth will be reported in a subsequent paper.

#### SUMMARY

1. Flower bud formation in the Camellia takes place abundantly where plants are maintained at temperatures of 80 degrees or above during the day and 65 degrees or above during the night, but is suppressed at lower temperatures.

2. Normal flower opening does not take place in Camellia plants maintained at high temperatures as 80 degrees day and night, in part owing to abscission of the flower buds and in part owing to the delayed production of small and abnormal flowers. Favorable temperatures for flower opening lie in the region of 65 degrees day and 60 degrees night, although other combinations of day and night temperature may prove as suitable.

3. It has been possible to produce normal Camellia flowers during the period March to September by subjecting vegetative plants to an 8-week period at 80 degrees (for bud initiation) followed by transfer to the 65 degree day, 60 degree or 55 degree night condition for flower opening.

4. The response of Camellia to temperature is modified by photoperiod, long photoperiods favoring flower bud initiation and slowing flower opening.

5. The number of flower buds produced by Camellia under favorable conditions of temperature and photoperiod is markedly influenced by light intensity, high light intensities increasing the number of flower buds set.

## Further Experiments in Pruning Old Rose Plants

By J. R. KAMP and F. F. WEINARD, *University of Illinois, Urbana, Ill.*

A CUTTING back experiment on three varieties of roses in the 1944-45 season (1) disclosed that the yield of flowers per plant increased with the mildness of pruning. Four-year-old plants cut back to 6, 12, 18 and 24 inches early in the summer averaged 9, 12, 13 and 15 roses per plant respectively without loss of stem length. Since the highest topping level tried gave the greatest yield of flowers, 1,338 plants in four varieties were cut back to 24, 30 and 36 inches in the 1945-46 season. Four-year-old plants of Better Times, Mrs. F. D. Roosevelt, Peters Briarcliff and Talisman were used. Each variety was planted on two of the four benches used in the experiment. Each treatment was replicated four times in each variety, 28 plants per replication, or a total of 112 plants of each variety per treatment.

Table I shows production records from October 1, 1945 to June 1, 1946. It will be noted that the results with the different varieties were

TABLE I—PRODUCTION RECORD FROM ROSE PRUNING EXPERIMENT

Plants Cut Back To	24 Inches	30 Inches	36 Inches
<i>Better Times</i>			
Number of plants.....	110	112	112
Average number of flowers per plant.....	18.71	20.28	21.91
Average stem length.....	15.05 in.	14.74 in.	14.58 in.
Total flowering wood cut per plant.....	281.58 in.	298.92 in.	319.43 in.
<i>Mrs. F. D. Roosevelt</i>			
Number of plants.....	112	112	112
Average number of flowers per plant.....	33.26	30.65	29.79
Average stem length.....	13.38 in.	14.00 in.	13.35 in.
Total flowering wood cut per plant.....	445.09 in.	429.03 in.	397.69 in.
<i>Peters Briarcliff</i>			
Number of plants.....	112	112	112
Average number of flowers per plant.....	20.31	22.68	22.00
Average stem length.....	14.38 in.	14.19 in.	13.78 in.
Total flowering wood cut per plant.....	292.06 in.	321.78 in.	303.13 in.
<i>Talisman</i>			
Number of plants.....	108	112	112
Average number of flowers per plant.....	28.22	29.97	27.43
Average stem length.....	13.70 in.	14.46 in.	14.02 in.
Total flowering wood cut per plant.....	386.69 in.	404.38 in.	384.53 in.

not uniform. The differences observed with Talisman were slight. Better Times, however, gave much better results at 36 inches than at 24 inches. The reverse was true with Mrs. F. D. Roosevelt. Peters Briarcliff was best when cut to 30 inches, and poorest at the 24-inch level. These differences are considered important not only because of their magnitude, but also because yields on both benches followed the same trends.

The difficulty in handling the higher topped plants should be considered. These plants required more tying, cutting of blooms was less convenient, and controlling red spider and mildew was more difficult.

The tallest plants were so near the roof glass that repeated sulfur treatments were sometimes necessary to combat mildew.

In spite of increased difficulty of handling, however, an increase of three flowers per plant as shown in the Table I seems to justify topping Peters Briarcliff as high as 30 inches and Better Times as high as 36 inches. This should be particularly true with plants grown in ground beds where difficulties in handling the taller plants would be minimized.

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## The Effects of Ceresan Dips and Fertilizer Applications on Growth, Flower Production, and Basal Rot Development in Narcissus

By NEIL W. STUART, *U. S. Department of Agriculture, Beltsville, Md.*

LITTLE information is available concerning the optimum nutrient requirements for growing narcissus. This may be due to the fact that in the bulb growing areas of the eastern United States, *Fusarium* basal rot (*Fusarium oxysporum* f. *narcissi* (Cke. et Mass.) Snyder and Hansen) is probably the most important factor in bulb production. While the severity of the disease varies from year to year, some fungicidal treatment is practiced annually by most commercial growers. This treatment, in order to effect some control of the disease, has tended to overshadow the importance of cultural practices including the use of fertilizers. It has been difficult to separate the effect of the various fertilizer elements on bulb growth from their effect on the disease. The purpose of the present study was to test the effect of certain fertilizer combinations on the growth and flowering of narcissus bulbs, some of which had been treated with a fungicide for basal rot control.

Fertilizer tests with narcissus have produced conflicting results. At Norfolk, Virginia, Parker concluded (4) that the value of fertilizer use depended upon whether flowers or bulbs were to be produced. Application of 1,000 pounds per acre of a 2-10-5 fertilizer resulted in fewer blooms but heavier bulbs. At Ithaca, New York, Allen reported (1) that narcissus fertilized at planting time responded with increased weight of bulbs produced, in the following order: 5-10-5 > rotted manure > ammonium sulfate > muriate of potash > superphosphate > control. No mention was made of the occurrence of basal rot which, if present, might have altered these results. Emsweller, Randall, and Weaver (2) used 20 fertilizer treatments at Castle Hayne, North Carolina, but observed no significant differences in yield of bulbs between any of the fertilizers used. The results on flower yields indicated a stimulation of new growth centers in the bulbs and higher flower yields following the application of 3 pounds of borax per acre. Smith noted (5) in Virginia that a fertilizer containing superphosphate, potash, and lime but no nitrogen produced the earliest flowers of good quality and bulbs of poor quality. At Beltsville, Maryland, tests have shown that the root-inducing growth substances and certain organic nitrogen compounds, particularly the nitrogen bases, stimulate the growth of *Fusarium* basal rot in culture and result in greater losses of bulbs in the field (6, 3).

The experiments described in the present paper have been made at the Plant Industry Station, Beltsville, Maryland, beginning in 1941. At the time they were started the fungicidal treatment in general use on Long Island and in North Carolina was one that had been developed by Frank Haasis at the Babylon Bulb Laboratory in New York. This treatment consisted in dipping the bulbs for 2 minutes in a



suspension of New Improved Ceresan (containing 5 per cent ethyl mercury phosphate) used at the rate of 1 pound per 40 gallons of water, after which the bulbs were dried rapidly in the sun and stored in a well-ventilated building. It was recommended that the treatment be applied within 3 days after the bulbs were harvested and again just prior to planting.

Narcissus bulbs of the King Alfred variety, grown at Beltsville, were harvested in July 1941, and half of them were dipped in Ceresan in July and again in September while the remainder were untreated. Both groups of bulbs were graded and from each were selected 24 lots of 100 bulbs, 50 bulbs being of the 12-14 cm size and 50 of the 14-16 cm size. The average weight of the lots was  $147 \pm 0.7$  ounces. The bulbs were planted in Dutch beds 3 feet wide and  $7\frac{1}{2}$  feet long containing 10 rows of 10 bulbs each. The fertilizers used comprised two levels each of nitrogen, phosphorus, and potassium in a  $2 \times 2 \times 2$  factorial arrangement replicated three times. The complete fertilizer formula was 4-8-8. The low level was none and the high level the full amount of each of the three elements derived respectively from sodium nitrate, superphosphate, and potassium chloride. The fertilizers were applied at the rate of 1 pound per bed and worked into the soil at the bottom of the bed before the bulbs were planted on September 26, 1941.

Flowers were counted on April 15, 1942, and the bulbs were harvested July 15 and 16. On July 20 bulbs showing basal rot were removed and half of the sound bulbs from each plot were dipped in New Improved Ceresan. The bulbs were dried in the sun and stored in a well-ventilated bulbhouse until September 16. At that time all lots were sorted for basal rot. Bulbs that had been double-dipped in Ceresan in 1941 were given a planting dip in 1942 while those undipped in 1941 were not given the planting dip. Accordingly, each of the following treatments was applied to 24 lots of bulbs from the fertilizer replications:

1. Undipped in Ceresan in 1941 and 1942.
2. Undipped in Ceresan in 1941, harvest dip in 1942.
3. Double-dipped in Ceresan in 1941 and 1942.
4. Double-dipped in Ceresan in 1941, planting dip in 1942.

Due to labor shortage the bulbs were planted in 1942 in single rows 3 feet apart instead of in Dutch beds. All of the apparently sound bulbs in a lot were planted 4 inches apart in a 25-foot row. The fertilizer was applied at the bottom of the plow furrow at the rate of 1 pound per 25 feet. Each of the fertilizer treatments was replicated three times with bulbs that had been grown with the same fertilizer in 1941. Since each lot of bulbs had been divided for Ceresan treatment there were four plots receiving the same fertilizer in each of the three randomized blocks.

Flowers were counted April 20, 1943, the bulbs harvested July 13 and 14 and 48 lots dipped in Ceresan on July 17. All were stored in the bulbhouse until September 10 when they were weighed and counted. Forty-eight lots were dipped in Ceresan and planted as in

1942. The same fertilizer treatments were continued. Flowers were counted April 22, 1944, the bulbs were harvested July 4 and 5, and 48 lots were dipped in Ceresan on July 8. Final counts and weights were made in September.

Data showing the effect of the Ceresan treatment in reducing losses of bulbs from basal rot are shown in Table I. In these data the weight

TABLE I—NARCISSUS BULB YIELDS FROM PLANTING UNTREATED BULBS AND FROM SIMILAR BULBS DIPPED ONCE OR TWICE PER YEAR IN NEW IMPROVED CERESAN (THE WEIGHTS GIVEN ARE FOR SOUND BULBS AT PLANTING TIME)

Year	Bulbs Not Dipped in 1941 (Pounds)		Bulbs Dipped in 1941 (Pounds)	
	No Dip 1942-1944	Harvest Dip 1942-1944	Planting Dip 1942-1944	Harvest and Planting Dip 1942-1944
1942	122.9	138.2	191.4	200.7
1943	122.8	208.4	323.8	333.0
1944	109.6	258.3	394.8	415.1

of sound bulbs at planting time from all fertilizer treatments and the unfertilized control are grouped together for each Ceresan treatment. The crop from bulbs that were not dipped in Ceresan at any time showed a net loss in weight for the three-year period. Bulbs given only the harvest dip in Ceresan yielded as of planting time in 1944 two and a third times as many pounds as the undipped bulbs. Bulbs that had been double-dipped in Ceresan in 1941 and had the single dip at planting time thereafter, yielded in 1944 more than three and a half times as much as the undipped bulbs; while those that had been double-dipped annually yielded slightly more. For the bulbs dipped in 1941, the differences in weight between those dipped once and those dipped twice annually thereafter were not statistically significant.

The effects of the various fertilizer combinations on bulb growth, flower count, and basal rot development are shown by the data in Table II. The data for all Ceresan treatments are combined in order to show the main effects of nitrogen, phosphorus, and potassium in the fertilizer. It is apparent that nitrogen in the fertilizer reduced the weight and number of bulbs and the number of flowers, and increased the amount of basal rot. The same effect, although to a lesser extent, was obtained with phosphorus. On the other hand, the presence of potassium in the fertilizer had exactly the opposite effect, increasing yields of bulbs and flowers and decreasing the amount of basal rot. In order to test the significance of these observed differences, the data for 1944 were calculated for analysis of variance. These calculations show that the differences in weight and number of bulbs and amount of basal rot due to the presence of nitrogen in the fertilizer were significant at the 1 per cent level. The data for number of flowers exceeded the 5 per cent but fell short of the 1 per cent level. The differences in yield caused by phosphorus and by potassium were too low for significance at the 5 per cent level; but the reduction in the number of bulbs with basal rot in the plots receiving fertilizers containing potassium was significant at the 1 per cent level.

TABLE II—WEIGHT AND NUMBER OF SOUND NARCISSUS BULBS, NUMBER OF BULBS WITH BASAL ROT, AND NUMBER OF FLOWERS FROM BULBS GROWN WITH LOW AND HIGH LEVELS OF NITROGEN, OF PHOSPHORUS, AND OF POTASSIUM

Fertilizers	Weight of Sound Bulbs (Pounds)			Number of Sound Bulbs			Number of Flowers			Number of Bulbs With Basal Rot		
	1942	1943	1944	1942	1943	1944	1942	1943	1944	1942	1943	1944
0-0-0, 0-8-0												
-N 0-0-8, 0-8-8	343.1	528.2	649.9	2,748	2,616	4,670	2,031	2,602	3,781	460	216	147
4-0-0, 4-8-0												
+N 4-0-8, 4-8-8	310.1	459.8	528.2	2,494	2,264	3,864	2,087	2,288	3,284	605	249	200
0-0-0, 0-0-8												
-P 4-0-0, 4-0-8	332.2	514.9	617.6	2,662	2,546	4,481	2,083	2,530	3,666	521	238	168
0-8-0, 0-8-8												
+P 4-8-0, 4-8-8	320.9	473.0	560.5	2,580	2,334	4,053	2,035	2,360	3,399	544	227	179
0-0-0, 0-8-0												
-K 4-0-0, 4-8-0	319.0	482.4	566.1	2,558	2,343	4,177	2,019	2,382	3,404	567	240	191
0-0-8, 0-8-8												
+K 4-0-8, 4-8-8	334.1	505.5	611.9	2,684	2,537	4,357	2,099	2,508	3,661	498	225	156

The total number of bulbs showing basal rot decreased each year from 1942 to 1944. The number of sound bulbs decreased from 1942 to 1943 and then showed a large increase. Neither of these measurements is as highly significant as the data for total weight of bulbs or the total number of flowers produced. All of the bulbs with basal rot are not recovered in harvesting and the total number of bulbs varies, depending upon the rate of propagation from rounds and mother bulbs. In this test slabs were separated before dipping in Ceresan and counted as bulbs. This was done only when the slabs could be removed easily without injuring the mother bulb, since such injury increases the chances of basal rot infection.

The effects of the fertilizers on yield were relatively small in comparison with the effect of the Ceresan, but they were very consistent, nitrogen and phosphorus reducing yields and potassium increasing them. These results are in agreement with the laboratory studies on the effect of nutrients on growth of the *Fusarium* in culture (3) and suggest that many fertilizer practices are of greater benefit to the *Fusarium* than to the narcissus. Other studies have shown that the source of the fertilizer element as well as the total amount may play an important role in disease susceptibility and consequent yield of bulbs. If the *Fusarium* could be more completely controlled it would be possible to determine the effect of the various fertilizer elements more accurately.

No information is available in this study as to the relative fertility level of the soil where the narcissus were grown. It is possible that better results would be obtained if the fertilizers were applied to a cover crop during the season before the bulbs are planted and little or none applied to the bulbs. In future work the factors of soil fertility, time, amount, and method of fertilizer application as well as varietal response will be considered.

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## Plant Exploration At Home

By A. F. YEAGER, *New Hampshire Agricultural  
Experiment Station, Durham, N. H.*

ALL of us are indebted to the work of our United States Department of Agriculture Office of Foreign Seed and Plant Introduction, and certain individuals for collecting and distributing new plant material from the ends of the earth which we may sometimes use directly — but more often indirectly — in our breeding programs for the development of new and better kinds of plants. Nevertheless, I am convinced that equally valuable material is to be found about us and under our feet, if we look for and recognize it. Unless it is something extraordinary, however, we are too prone to overlook it altogether. A few examples of native plants which have been used to good advantage include such things as our native wild plum, sand cherries, apples, grapes, strawberries, raspberries, blackberries, gooseberries, and blueberries. These have either been domesticated themselves or used in crossing with foreign stocks, to produce named varieties. The tendency among plant breeders from this point has been to assume that now we have the characteristics of the species in the new variety and that our job now is to continue breeding work by selecting within these cultivated varieties and by recrossing between these cultivated varieties, recombine these characters. This we have done until these fertile fields have been depleted. The fallacy of this comes from the assumption that when we take a wild plant representing a species, we have thereby introduced into our strain the total of the characteristics of that wild species. This is not true. I believe that there is more variability between wild plants of the strawberry (*Fragaria virginiana*) collected over its range than there is between our cultivated varieties. Each wild plant consists of a collection of genes, but this collection may differ in many respects from that carried by any other wild plant. Certainly variability in firmness of berry exists in wild plants from the very softest fruits to those that are much harder than any cultivated sort. The color varies from light to very dark red. Some fruits have large, white cores; others have red flesh all the way through. There are long berries and round berries; sweet berries and sour berries; some with much aroma; some with very little. Some of the plants are adapted to acid soil, some to alkaline soil. Some are tall and some are short; some early and some late. Some are very susceptible to leaf spot and others nearly immune to it. If one then is to cross a cultivated strawberry with a wild strawberry, the results he might secure will differ with the wild plant used. It is folly to assume that the wild strawberry crosses made one hundred years ago to produce the forerunners of our cultivated sorts just happened to contain all of the good things that there are in the wild strawberry. Obviously the thing needed to get new characteristics into strawberries is to search among the wild plants, select those which possess characteristics that are desired and use those in our breeding work. In whatever locality we are doing our work, the probability is that the best plant to use for

our breeding purposes in producing adapted varieties is the one which grows in that neighborhood. Cultivated strawberries are classed as acid soil loving, probably because of their acid soil loving ancestors. Obviously, one who lives in a region where alkaline soils prevail should use native wild strawberries adapted to those alkaline soils for his breeding work. He may also pick up unexpected dividends. The writer made wild strawberry selections in North Dakota which were sent to Washington for possible use in the work of the United States Department of Agriculture. In 1946, they are reported as withstanding temperatures of 20 degrees above zero while in full bloom. The blossoms on named varieties were killed. Most of our breeding work consists of adding one desired character at a time. The frost resistance of these particular plants may thus be of great importance in the improvement of strawberries.

Since it is obviously impossible to discuss all the plants in detail, may I now point out a few of the wild plants which probably possess characteristics which we need. The everbearing characteristic is quite common in wild raspberry plants, though not utilized until recently. Doubtless disease resistance is present if looked for. In blackberries, the near thornlessness of *Rubus Canadensis* is a feature blackberry breeders might well use.

There probably is not a single wild plant, even those which have been used most in plant breeding work, which has been completely explored in its native habitat. This is particularly true in the light of modern plant breeding methods wherein individual characteristics are considered rather than the plant as a whole. Early exploration consisted largely in collecting those individuals which, considering everything added together, came the nearest to meeting our idea of a satisfactory cultivated plant. Hence, there has probably been a great overemphasis on size and flavor for which there are other sources, as contrasted to such less obvious things as disease resistance, for example, or the hundreds of other inconspicuous, though much needed, characteristics which, put together, go to make up what we call a variety. If this be true of those things we have used the most, what can we say of those which have not so completely occupied the spotlight. A careful observer with an open mind has an abundant opportunity to exercise his talents as a plant explorer anywhere.

The following are a few of the good prospects for more observation: hazel nut, black walnut, shagbark hickory and butternuts; pin cherries, choke cherries, Amelanchier, elderberry, Viburnum, pawpaw, persimmon, and hawthorn. Among the ornamentals, which are perhaps the most neglected of all, there are such things as Philadelphus, mountain laurel, honeysuckle, black elder (also known as wild holly), wild lilies, wild asters, rhodora, and redbud. As for vegetables, many of those used by the American Indians before the coming of the white man have been permitted to lapse into oblivion. There is a question as to whether we might not use other species of Solanum, which one by one have been finding their way into the fold of the useful food group; even *Solanum triflorum*, which is listed by botanists as a poisonous plant, may have something in it that would be of use to a plant breeder. It

grows in dry areas unsuited to most other vegetation. While it is classed as a poisonous plant, the accuracy of this classification might be challenged, inasmuch as the writer, after forcing crushed berries down the gullet of an unwilling rabbit to determine whether they were harmful, learned that this operation was unnecessary since the rabbit, when released, ate the fruit readily without compulsion.

Dr. L. C. Curtis has opened up entirely new possibilities in the Cucurbits by the collection and utilization of the wild perennial Cucurbits of the southwestern United States in his breeding work from which he is developing plants for oil and stock feed production.

Backyard gardens of our amateur horticulturists are also promising fields for plant exploration. One of our projects at the New Hampshire Experiment Station has been the collection of the many varieties and forms of beans which have been grown in family gardens in the New England area through many generations; even many of those which look alike prove not to be the same when grown in comparative trials. We have four distinct strains of Jacob's Cattle, for example. Unusual disease resistance and certain unusual colors and flavors have been dividends from this exploration project. Jewett, New Hampshire Red Kidney and Cowey Red Lima have been distributed as results of this project. I think there is no question but that thousands of exceedingly useful plants from the plant breeder's point of view remain thus to be discovered in someone's back yard, secretly prized and utilized but not advertised.

The hillsides of northern New England north of the range of standard apple varieties are dotted with thousands of apple seedlings planted there by animals from forgotten unsuccessful orchards. These should be studied with a critical eye; something important may be there. The thousands of naturalized sweet cherries in Pennsylvania should be studied. No doubt you could supply similar cases.

By all means, let us have foreign plant exploration but at the same time one need not feel that the exploration field is for someone else when such a land of opportunity lies all about him.

# Horticulture Research and Teaching in California<sup>1</sup>

By WARREN P. TUFTS, *University of California, Davis, Calif.*

THE term "Horticulture" at the University of California has for many years been used to designate the field of fruit culture and the term "Pomology" reserved for that portion of the subject which has to deal with the growing of deciduous tree fruits and small fruits other than the grape. Instruction given by the administrative divisions of Pomology, Subtropical Horticulture, Ornamental Horticulture, and Viticulture are all listed as horticultural courses. Instruction in vegetable production is not included under Horticulture but listed as Truck Crops.

It is my intention to narrate at least some of the steps in the development of the present horticultural curriculum and program of research which have taken place during the past 35 years.

At this point I am perhaps as confused in my thinking as were the little moron and his little moron helpers who were building a house, understand!

So the little moron went to the boss and asked him should they build it from the top down or from the bottom up.

"Why, build it from the bottom up, of course!" the boss replied.

The little moron turned and yelled to his helpers: "Tear 'er down boys! We got to start all over!"

I will have to let you decide whether we are building from the top down or the bottom up and whether we should tear our whole structure of curriculum and research program down and start all over.

Although only about 12 per cent of our resources, whether measured by men's time or money spent, is devoted to resident teaching, leaving 85 per cent for research and 3 per cent for extension, it seems to me that all three activities are or should be inextricably interwoven.

It is my judgment that the research worker will do better in his investigational activities if during one semester each year he has the responsibility for, let us say at least one three-unit course. This will necessitate his keeping up to date with advances in the whole field of horticulture rather than in only his own narrow or specialized line of research. Students at the University level are a distinct spur to the intellectual development of the teacher, and in turn should not be denied the inspiration which comes from close association with the productive investigator, if he is also a good teacher. It is important also that a worker on agricultural problems should have some contact with the farmers of his state—as was so ably pointed out by Dr. Lief Verner in his address to The Western Section of the American Society for Horticultural Science at the Reno meetings in 1946. By this I do not mean that the Experiment Station should devote all its efforts to the solution of immediate and practical problems but should bear in mind that farmers, and fruit growers particularly, are an intelligent group and are willing to await a solution of their problems but do

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<sup>1</sup>Address given at the Annual Meeting of the Western Section of the American Society for Horticultural Science, San Diego, Calif., June 17, 1947.



appreciate a "progress report" and suggestions arising from unfinished research which while not final, may be worthy of a trial on a limited scale. Therefore, I am convinced that a certain amount of extension work is an excellent stimulus to the investigator and he may many times receive ideas for a new approach to his problem from the man who makes his living from the soil.

### TEACHING

It is perhaps now time that I should give some attention to the "bottom" rather than parts of the superstructure. As implied above instruction in horticulture both at the undergraduate and graduate levels are foundations on which we must build the research program. The horticultural teacher and investigator must be furnished with proper tools for his profession and these are the knowledge and techniques acquired during both the undergraduate and graduate years. He must know his material, both the art and science of horticulture, and be well grounded in the several sciences upon which the field of horticulture is based. If he is fortunate enough to have had a background of farm experience so much the better.

About 25 years ago the College of Agriculture of the University of California made two rather drastic innovations so far as undergraduate instruction was concerned: First, instead of requiring all students to complete elementary courses in a number of *agricultural subjects*, which is still the standard procedure in many agricultural colleges of the United States, certain basic courses in the *sciences* were required, the distribution and emphasis depending somewhat on whether the student was more interested in plants or animals. However, the requirements for the first year were practically identical so that there was no immediate need at matriculation to make the choice of a major. Second, encouragement, if not actual coercion, was given to the divisions offering work in the various branches of agriculture to reduce the number of courses to the minimum and yet allow the student some latitude during his Junior and Senior years in securing the 12 units in his major subject which are required out of a total of 124 units necessary for the B.S. degree. At the same time, the requirement of a thesis for the B.S. degree was eliminated. This was a good move, since, because of the nature of pomological material, the thesis work in most instances had to be initiated during the Junior year before the student had even a meager background in the subject. As a result of this policy it has been impossible for the student in Horticulture at the University of California to secure anywhere near the same number or proportion of units of Pomology as he might have at any number of other agricultural institutions. A quarter century of experience of requiring as many or more units each of botany and of chemistry as of pomology leads us to the conclusion that this is sound educational policy whether the student is being trained to return to the farm, to enter business pertaining to agriculture or to proceed with graduate work looking towards professional work in agriculture. Former students state that their training in the sciences has been of greater value in evaluating new horticultural practices and materials

than additional horticultural courses would have been. The few changes which have been made through the years have had a tendency to broaden the student's foundation rather than towards greater specialization.

For the master's degree in horticulture we have, in general, insisted on additional basic course work rather than emphasizing the presentation of a formal thesis. The student is required to do a satisfactory bit of research but instead of presenting a thesis he must stand an oral examination based in part upon his research but largely designed to determine his breadth of understanding of the whole field of horticulture, both practical and theoretical, and the sciences basic to horticultural practice. This general procedure for the master's degree has proved satisfactory.

Another education experiment initiated some 15 or more years ago in several departments of the University was the institution of "Fields of Study" leading to the Ph.D. degree, cutting across long established academic departmental boundaries. In most instances the lines of demarcation were drawn on the basis of certain disciplines, such as: Animal nutrition, comparative physiology, genetics, plant physiology, and soil science. Under this scheme, horticulture was eliminated as a major and no incentive presented to encourage the horticultural student to maintain intimate contact with developments in his chosen profession.

By this device of Fields of Study a professor whether agronomist or horticulturist, whose training and interests are in some phase of plant physiology may be elected by his peers in other academic departments to participate in deciding upon minimum requirements and may direct, examine and approve candidates for the doctor's degree in plant physiology. As a consequence we have professors of horticulture for students at the undergraduate level and for candidates for the master's degree, but for the occasional candidate for the doctor's degree the same man must become a geneticist, a morphologist, a taxonomist or a physiologist and as such maintain scholarship at a high level, not only as a horticulturist on the basis of which he received his appointment and expects advancement, but also in one or more of the disciplines above mentioned if he is interested in guiding graduate students. In view of the great advances that have been made in all the sciences impinging on horticulture during the past 20 years and especially during the past few years, it is my considered judgment that a man cannot in this age of specialization be an outstanding horticulturist and at the same time have the intimate knowledge in such fields as genetics, ecology, plant morphology, and plant physiology, necessary for the direction of graduate students in these disciplines. To my mind a system where there is a possibility of selecting Horticulture as the major subject and in addition one or two minor subjects such as plant anatomy and plant physiology is ideal. In this way intimate contact is maintained by the horticultural staff with the student throughout his graduate years to the end that he may be placed most advantageously for his future development and progress. I must conclude that from the standpoint of both the student and faculty, our

present arrangement of forcing all horticultural students interested in proceeding to the doctorate to specialize in one of the closely allied disciplines more or less to the exclusion of further work in horticulture has proved after a thorough trial in most instances to be unsatisfactory.

#### RESEARCH

Over the years considerable thought has been given to the organization of the research program in pomology at the University of California. From about 1900 to 1910 there was one group in the institution which thought that there was no need for experimental orchards — that in order to learn the "facts of life" it was only necessary to observe the practices of the most successful growers and that these should be the basis of instruction at the University. Between 1910 and 1920 some attempt was made to organize pomological research on a crop basis and to have prune, apple, pear, cherry, walnut, and so on specialists, following about the same pattern of organization as that of the United States Department of Agriculture.

It soon became apparent, however, that the work in general should be organized horizontally rather than vertically — in other words, on the basis of techniques that would be equally applicable to all species. Thus was organized the cooperative project on irrigation of fruit trees under the guidance of Hendrickson of Pomology and Veihmeyer of Irrigation, both trained in plant physiology with the former specializing in water relationships within the plant and the latter paying more particular attention to soil moisture in its relation to plant growth. The specialized techniques devised by these men have been applied successfully to all species. How futile it would have been for a specialist in each fruit to have attempted to develop the techniques perfected by these investigators over the years in order to study the irrigation problems of his particular species.

Following this general pattern we have established such general Experiment Station projects, with one or more workers in charge, as: pollination, pruning, orchard soils, (subdivided into cover crops, cultivation, nitrogen, potash, and phosphorus, zinc, boron, sodium and other elements), rootstocks, fruit thinning, climate in relation to fruit growing, fruit breeding, fruit morphology, varietal adaptation, fruit harvesting, handling, precooling, shipping and storage studies.

As the years have passed, new problems have presented themselves which because of our ignorance of the factors involved could not be assigned to one of the workers in charge of the general projects as outlined above, or which because of the very nature of the problem divided itself among two or more of the above categories and thus necessitated a new general project. As an illustration of the former, zinc deficiency studies were first undertaken as a project entitled "Little Leaf or Rosette of Fruit Trees"; examples of the second are: "Black End of Pear", "Split-pit of Peach", and "Factors Influencing the Reestablishment of Peach Orchards in Old Peach Soils".

The above approach to the pomological problems of California has proved entirely satisfactory except for one weakness. It has failed, in itself, to develop men with detailed and intimate knowledge of the

materials and problems of our specialized fruit industries. This knowledge is fundamental to Experiment Station service. In an effort to remedy this situation we have assigned to staff members responsibility for one or more crops, attempting in this assignment to give each man the fruit with which he has come to be most familiar in the course of his research work. For example, the man studying the, now, more or less academic problem of "Black-end of Pear", has acquired, during his investigations, a background of information regarding this fruit.

Of more recent years there have developed pressure groups representing certain fruit industries and it has been necessary to make staff additions of so-called crop specialists with such fruits; however, so far as possible it is our plan to have these specialists function as liaison officers between the industry and those staff members in charge of the irrigation, pruning, fertilization, root-stock, and other general projects. In order that these recently appointed crop specialists may not be handicapped professionally by becoming an expert in one of California's specialty crops and therefore not considered for positions in other states where such crops are not grown, we are encouraging these men to develop special fields of interest which may cut across all species. For example, the olive specialist is interested in the inter-relationship of temperature and length of day on fruitfulness and vegetativeness of fruit plants, using the strawberry as his initial material. Although we have a few men who have only the Experiment Station title and thus largely are relieved of teaching responsibilities, we are firmly convinced that for their own professional advancement, for the raising of the level of instruction and the improvement of industry contacts, all staff members should have academic as well as Experiment Station titles and should participate in teaching and extension. It is interesting to note that at Cornell all men are "professors", and have no Experiment Station title. They may do only teaching or research or may do both.

In the University of California no "iron curtains" limit the boundaries of divisions which have been established for administrative purposes. The only limitations set are those of the worker himself: his knowledge and techniques. This policy has resulted in many splendid truly cooperative projects between men in the same division or in different divisions. No attempt is made to force workers to cooperate since it has been our experience that unless the cooperative project is the desire of the men themselves it results in one worker doing the "cooking" and the other the "operating", and dissatisfaction results upon publication because credit is generally not given where credit is due. This moves me to gratuitously interject the observation that administrative heads are all too prone to affix their names to publications where their only contribution has been possibly suggesting the problem and approving the resulting manuscript. The administrator should be judged not by his own publications but by the quality of the contributions of his staff. It is also my conviction that some investigators are prone to publish prematurely. Laboring under the misapprehension, which may not be a misapprehension in some institu-

tions, that their advancement depends upon the number rather than the quality of their publications, they are tempted to begin an experiment with one hand and at the same time with the other write up their conclusions. It is my experience that those investigators whose work is of the highest quality, are perhaps too slow or over-cautious in publication and have to be constantly urged to present their findings on the printed page.

Returning again to the organization of the agricultural research program in California, I call your attention to the statement to the effect that no hard and fast lines of demarcation between divisions are drawn. However, we in pomology regard our field as encompassing all production, harvesting and handling and storage operations which the fruit grower normally performs, including the varietal and physiological problems incident to packaging, precooling, transportation, storage and marketing of fresh fruits and the same type of problems with fruits which are processed by drying, freezing, or canning. We regard studies involving technological developments as in general beyond our interest. There is considerable question in my mind as to the advisability of the University concerning itself with technological problems which industry in general is better equipped to solve; examples: packaging of dried and canned fruit, cannery machinery and processes, and so on. Certainly the study of varieties and their adaptation to environmental conditions as influencing the quality of the processed product is our concern.

What proportion of the total resources available for agricultural investigation should be spent on pure or fundamental, whichever term you prefer, and what proportion on applied or practical research? In the final analysis we in an agricultural experiment station owe our first responsibility to the industry we serve. Nevertheless, I am convinced that we would be derelict in our duty if we did not devote much effort to the accumulation of a considerable "back-log" of knowledge, to be drawn upon from time to time in the future in the solution of new problems as they arise. Unless we keep this objective firmly in mind we will be in the unenviable position of following rather than leading our industry. Undoubtedly the proportion of effort spent in "pure" research must vary from time to time and from station to station depending upon available funds and personnel. It is difficult not to be drawn too much towards the solution of immediate problems and to overlook the importance of having facts at hand to help in the solution of new and even more pressing problems which are bound to arise in the future. In the last analysis the man in charge of the overall research program must assume the responsibility as to the manner and on what problems his staff devotes its time.

Some institutions have seen fit to organize its staff so that one corps of workers devotes its time to so-called fundamental research and another corps to applied or industrial research. In my opinion this is a mistake. Workers in pure research soon become alienated not only from their fellow workers in the applied field but also from growers who are intensely interested in a solution of their immediate and pressing problems. As the years pass this super-scientific staff

becomes an increasingly difficult administrative problem since it cannot assume its fair share of the teaching and extension activities which are an integral part of our job as staff members of a College of Agriculture. These men with specialized training are the very ones who with years of experience should assume the leadership in a department both as teachers and as contact men with the industry.

Somewhat allied to the question as to the proper emphasis which should be placed on pure research, is the problem as to the proper approach to a new horticultural investigation. We find trees in the orchard not thriving and exhibiting symptoms with which we are not familiar; the plant pathologists and entomologists disclaim any responsibility; shall the horticulturist attempt a solution by means of field or laboratory experiments? In general it takes a worker with wide experience in the field to even suggest a possible attack. It has been our observation that field experiments supplemented by laboratory studies are the most likely to give the first leads to an ultimate solution. Later emphasis may be given to the laboratory work but the final proof is always in the field. The solution of the problem of "Little Leaf" and "Rosette" of deciduous and "Mottle Leaf" of citrus trees furnishes a classic example.

True research cannot be directed — there is no real significance in the title, Director of Research. The administrative officer in charge of a research program can only point out the problem, select the man who in his judgment has the techniques and experience most likely to be useful in its solution, and provide the necessary facilities and encourage the worker from time to time. The real investigator is one to whom his work is fun, who would rather be doing what he is than anything else in the world.

These random thoughts to which I have attempted to give expression lead me to my final statement. In order to build our house, that is, our program of teaching and research, from the bottom up, it seems to me that the foundation will only be as strong as the men who make up the teaching and research staff of a horticultural department. In the final analysis it is the calibre of its faculty which determines the greatness of a University. What then should be the qualifications of these men?

At the University of California for many years we have required that all new appointees to the regular staff shall have received the Ph.D. degree, or at least have attained comparable training and experience. It is admitted that there are perhaps just as good men available without the degree, but the degree certainly is a convenient yard-stick and apparently the best criterion at present available. I am convinced that the worker who is most likely to succeed in the field of horticulture is one whose first love was agriculture as demonstrated by the fact that his undergraduate training was in agriculture. With this as a backyard his graduate years should be devoted largely to gaining competence in one or more of the disciplines upon which our Science is based. It is difficult at best to bring about the metamorphosis of a botanist or chemist into a horticulturist even after years of exposure to the field within a horticultural department.

# Register of New Fruit and Nut Varieties

## List No. 3

Compiled by REID M. BROOKS and H. P. OLMO, *University of California, Davis, Calif.*

### COOPERATING HORTICULTURISTS

Alabama: T. B. Hagler. Arizona: A. H. Finch. Arkansas: J. E. Vaile. California: W. E. Lammerts, M. B. Rounds, C. A. Schroeder, H. C. Swim. Canada: A. W. S. Hunter, E. P. Palmer. Connecticut: D. F. Jones. Delaware: L. R. Detjen. Florida: F. E. Gardner, S. J. Lynch, Geo. D. Ruehle. Georgia: M. M. Murphy, Jr., J. H. Weinberger. Idaho: Leif Verner. Illinois: R. L. McMunn. Indiana: C. E. Baker, C. L. Burkholder, Laurenz Greene. Louisiana: J. C. Miller. Maryland: G. M. Darrow, C. A. Reed. Michigan: Stanley Johnston. Minnesota: A. N. Wilcox. Mississippi: E. A. Currey, N. H. Loomis. Missouri: Paul Shepard. New Hampshire: L. P. Latimer. New Jersey: M. A. Blake. New Mexico: J. V. Enzie. New York: John Einset, G. H. Howe, G. D. Oberle, G. L. Slate, Richard Wellington. North Carolina: M. E. Gardner, C. F. Williams. Ohio: Freeman S. Howlett. Oklahoma: F. B. Cross. Oregon: Henry Hartman, C. E. Schuster, Geo. F. Waldo. Pennsylvania: F. N. Fagan. South Carolina: John T. Bregger. South Dakota: N. E. Hansen. Tennessee: Brooks D. Drain, J. C. McDaniel. Texas: E. Mortensen. Utah: Francis M. Coe. Vermont: M. B. Cummings. Virginia: R. C. Moore. Washington: C. D. Schwartze. West Virginia: W. H. Childs, Edwin Gould. Wisconsin: James G. Moore. Wyoming: W. O. Edmondson.

### REVISIONS, LIST NO. 1<sup>1</sup>

#### PEACH

**Sungold.**—Prof. T. J. Maney of Iowa State College was the first to recognize its possible value and first called it to public attention about 1924. Rights to propagation assigned to Interstate Nurseries, Hamburg, Iowa.

#### STRAWBERRY

**Corvallis.**—Patent no. 60; April 18, 1933; dedicated, by mesne assignments, to the People of the United States of America.

### REVISIONS, LIST NO. 2<sup>2</sup>

#### AVOCADO

**Ryan** (*Summer Fuerte*).—Originated in Whittier, California, by A. R. Rideout.

*Summer Fuerte.*—See **Ryan**.

**Zutano.**—Probably a hybrid between Mexican and Guatemalan races.

#### CHERIMOYA

**Ott.**—Originated in Mexico City, Mexico.

#### NECTARINE

**Hunter.**—A nectarine.

### LIST NO. 3

#### APPLE

**Alaska.**—Originated in Ettersburg, California, by Albert F. Etter. Introduced commercially in 1944. Patent no. 699; June 18, 1946; assigned to George

<sup>1</sup>*Proc. Amer. Soc. Hort. Sci.* 45: 467-490. 1944.

<sup>2</sup>*Proc. Amer. Soc. Hort. Sci.* 47: 544-569. 1946.

C. Roeding, Jr., California Nursery Company, Niles, California. Open pollinated seedling of Bedfordshire Foundling; selected in 1944. Fruit: flesh snow white; skin shiny; medium sized. Tree: heavy producer.

**Atha.**—Originated in Cullman County, Alabama, by Miss Atha Warnick. Introduced commercially about 1930. Open pollinated seedling of Red Astrachan (perhaps x Yellow Transparent); selected about 1915. Fruit: firmer, ripens six weeks later, and less tendency to biennial bearing than Yellow Transparent. Tree: most nearly resembles Yellow Transparent, but more vigorous.

**Dark-Red Staymared.**—Originated in Barber, Allegheny County, Virginia, by B. C. Moomaw, Jr. Introduced commercially in 1927. Trademarked by Stark Brothers Nursery, Louisiana, Missouri. Bud mutation of Stayman Winesap. Fruit: skin darker red than that of parent.

**Etter's Gold.**—Originated in Ettersburg, California, by Albert F. Etter. Introduced commercially in 1944. Patent no. 659; August 28, 1945; assigned to George C. Roeding, Jr., California Nursery Company, Niles California. Parentage unknown. Fruit: matures in October; skin golden yellow; flesh crisp.

**Fireside (Minnesota No. 993).**—Originated in Excelsior, Minnesota, by the Minnesota Agricultural Experiment Station (Charles Haralson). Introduced commercially in 1943. Parentage unknown; selected in 1917; selected for further testing in 1927. Fruit: large (3 inches in diameter); skin medium red, lightly striped with darker red; flesh yellowish, medium coarse, medium tender, medium juicy; flavor mild subacid; quality excellent for dessert purposes; season of use November to April. Tree: hardy; vigorous; resistant to cedar rust but is only slightly less susceptible than Wealthy to apple scab and fire blight.

**Frostproof.**—Originated in Mineral, Virginia, by Max Bazzanella, of the Max Nursery. Introduced commercially in 1947. Patent no. 722; January 7, 1947. Parentage unknown; discovered in 1930. Fruit: bronze with russet, quality fair;  $2\frac{1}{4}$  to 3 inches; matures with Winesap; most nearly resembles Rustycoat. Tree: blooms 30 days later than most apples usually do.

**Idagold.**—Originated in Moscow, Idaho, by the Idaho Agricultural Experiment Station (Leif Verner). Introduced commercially in May, 1944. Esopus Spitzenburg x Wagener; selected in 1939. Fruit: high dessert and keeping qualities; most nearly resembles Esopus Spitzenburg.

**Jonwin.**—Originated in Ettersburg, California, by Albert F. Etter. Introduced commercially in 1944. Patent no. 710; September 17, 1946; assigned to George C. Roeding, Jr., California Nursery Company, Niles, California. Jonathan x Baldwin; selected in 1944. Fruit: large, size of Baldwin which it most nearly resembles; ripens during Jonathan season.

**Lizakowsky.**—See Saint Clair.

**Margaret Pratt.**—Originated in Owen Sound, Ontario, Canada, by C. A. Fleming. Introduced commercially about 1938. Parentage unknown; discovered before 1923 in the garden of Margaret Pratt. Fruit: most nearly resembles Red Astrachan but is larger; should be picked early since it breaks down if allowed to take on full color; used for cooking. Tree: appearance and performance similar to Red Astrachan; good bearer.

**Minnesota No. 396.**—See Victory.

**Minnesota No. 993.**—See Fireside.

**Payette.**—Originated in Moscow, Idaho, by the Idaho Agricultural Experiment Station (Leif Verner). Introduced commercially in May, 1944. Ben Davis x Wagener; selected in November, 1936. Fruit: large; good red color, high dessert quality; most nearly resembles Ben Davis.

**Pink Pearl.**—Originated in Ettersburg, California, by Albert F. Etter. Introduced commercially in 1944. Patent no. 723; March 4, 1947; assigned to George C. Roeding, Jr., California Nursery Company, Niles, California. Open pollinated seedling of "Surprise," selected June 23, 1944. Fruit: transparent skin which glows pink from flesh beneath; outstanding bouquet when skin is broken; ripens in September.

**Red Delicious.**—See Redwin.

**Redgold.**—Originated in Cashmere, Washington, by F. A. Schell. Introduced commercially in 1946. Patent no. 720; assigned to Stark Brothers



Nurseries, Louisiana, Missouri, December 24, 1946. Golden Delicious x Richared Delicious; selected about 1936. Fruit: fine flavor; red; matures fairly early. Tree: bears early.

**Red Gravenstein.**—Originated in San Juan County, Washington, by Van Sent V. Whipple. Introduced commercially in 1924. Bud mutation of Gravenstein; discovered in 1907 or 1908. Fruit: solid dark red; superior in appearance to Gravenstein or to Banks Gravenstein.

**Red Hackworth.**—Originated in Morgan or Cullman County, Alabama; originator unknown. Introduced commercially by Empire Nursery and Orchard, Baileyton, Alabama, about 1925. Probably an open pollinated seedling of Hackworth; selected before 1900. Fruit: quality good when fully ripe (August); smaller, firmer, and more solid red than Hackworth. Tree: well adapted to Alabama climate and soils; good understock variety in northern Alabama where it is propagated on own roots from suckers. Most nearly resembles Hackworth in tree and in flavor of fruit.

**Redwin (*Red Delicious*).**—Originated in Peshastin, Washington, by J. L. Johnson. Introduced commercially in 1928. Bud mutation of Delicious; discovered in 1925. Fruit: colors early, retaining dark red stripes at full maturity.

**Rome Beauty Double Red.**—Originated in Wapato, Washington, by E. E. Cowin. Introduced commercially in 1927. Trademarked by Stark Brothers Nurseries, Louisiana, Missouri. Bud mutation of Rome Beauty; discovered in 1925. Fruit: skin more highly colored than that of parent.

**Saint Clair (*Lisakowsky*).**—Originated in Lebanon, Saint Clair County, Illinois, by Mr. John J. Lizakowsky. Introduced commercially in 1935. Parentage unknown, raised from seed of an apple purchased from a train vendor in 1913 or 1914. Fruit: large; quality good; matures in summer; nearly solid red when grown in Lebanon, Illinois. Tree: strong; productive; adaptable to growing in Alabama.

**Victory (*Minnesota No. 396*).**—Originated in Excelsior, Minnesota, by the Minnesota Agricultural Experiment Station (Charles Haralson). Introduced commercially in January 1943. Probably an open pollinated seedling of McIntosh; first fruited in 1918. Fruit: holds well on tree; flesh and skin not as tender as McIntosh which it most nearly resembles; skin medium red; flesh white, fine-grained, juicy, aromatic; season of use October 15 to March 15; dessert variety.

**Wealthy Double Red.**—Originated in Sodus, New York, by James G. Case. Introduced commercially in 1940. Trademarked by Stark Brothers Nurseries, Louisiana, Missouri. Bud mutation of Wealthy; discovered in 1933. Fruit: resembles parent except that fruit is of a darker red skin color.

**Willow Twig Double Red.**—Originated in Hardin, Illinois, by C. F. Braden. Introduced commercially in 1929. Trademarked by Stark Brothers Nurseries, Louisiana, Missouri. Bud mutation of Willow Twig; discovered in 1927. Fruit: resembles parent variety except for darker red skin color.

#### APRICOT

**Bowers.**—Originated in Yakima County, Washington, by William I. Bowers. Introduced commercially in April, 1943. Patent no. 630; June 27, 1944. Parentage unknown; discovered in 1930. Fruit: early; large; high color; good canner; fine flavor and texture. Tree: heavy bearer; most nearly resembles Riland.

**Earle Orange.**—Originated in Grandview, Washington, by W. L. Roberts. Introduced commercially in 1945. Patent no. 674; April 2, 1946; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; discovered in 1920. Fruit: flesh deep orange in color; crimson blush on skin; ripens 10 days earlier than Riland at Grandview; ripens evenly. Tree: upright growth; blooms later than most late-maturing varieties.

**Phelps.**—Originated in the Yakima Valley, Washington, by B. F. Phelps. Introduced commercially about 1938. Parentage unknown; discovered about 1934. Fruit: ripens very early and evenly; very large; quality good; excellent shipper; flesh yellow; skin with red blush.

**Reeves.**—Originated in Burbank, California, by William H. Reeves. Introduced commercially in 1947. Patent no. 693; June 4, 1946; assigned to Armstrong Nurseries, Inc., Ontario, California. Parentage unknown; discovered about 1939. Fruit: ripens approximately 1 month before Royal and about 2 weeks before Newcastle; superior in flavor, skin color, and size to Newcastle; poor shipper. Tree: chilling requirement similar to that of Newcastle.

#### BLACKBERRY

**Big-Ness (Texas R40-51).**—Originated in College Station, Texas, by the Texas Agricultural Experiment Station (S. H. Yarnell). Introduced commercially October 31, 1946. Plant selected in 1940 from  $F_3$  of *Rubus rubrisetus* x Nessberry. Fruit: large; season early; most nearly resembles Mammoth. Bush: vigorous; resistant to little-fruit.

**Cameron.**—Originated in Raleigh, North Carolina, by the North Carolina Agricultural Experiment Station (Carlos F. Williams). Introduced commercially in 1938. Young x Lucretia; selected from a cross of 1930. Fruit: shiny black; larger and sweeter than Lucretia which it most nearly resembles. Bush: productive; vigorous; disease resistant; dewberry-type.

**Earli-Ness (Texas R40-4).**—Originated in College Station, Texas, by the Texas Agricultural Experiment Station (S. H. Yarnell). Introduced commercially October 31, 1946. Plant selected in 1940 from  $F_3$  of *Rubus rubrisetus* x Nessberry. Fruit: earliest maturing variety known. Bush: vigorous; resistant to little-fruit; most nearly resembles Early Wonder.

*Kosmo.*—See *Kosmos*.

**Kosmos (Kosmo).**—Originated in Oregon City, Oregon, by Percy W. Meredith. Not introduced commercially. Patent no. 39; October 25, 1932. Parentage unknown. Fruit: berry very soft. Bush: very susceptible to leaf spot.

**Olympic.**—Originated in Vashon, Washington, by Peter Erickson. Introduced commercially in 1930. Patent no. 247; April 20, 1937; assigned to H. F. Greider, Vashon, Washington. Young x Plum Farmer?; selected about 1929. Fruit: claimed to be larger, darker, and sweeter than Young; but similar if not identical with it.

**Regal-Ness (Texas R40-202).**—Originated in College Station, Texas, by the Texas Agricultural Experiment Station (S. H. Yarnell). Introduced commercially October 31, 1946. Plant selected in 1940 from  $F_3$  of *Rubus rubrisetus* x Nessberry. Fruit: matures early; most nearly resembles Earli-Ness. Bush: vigorous; resistant to little-fruit.

*Texas R40-51.*—See *Big-Ness*.

*Texas R40-4.*—See *Earli-Ness*.

*Texas R40-202.*—See *Regal-Ness*.

#### CAROB

**Santa Fe.**—Originated in Santa Fe Springs, Los Angeles County, California, by Lawrence Holmes of the California Carob Plantations. Introduced commercially in 1922. Selection made from a wild tree in 1920; this original tree was still alive in 1946. Fruit: large. Two plantings were made: one at Riverside, California, which is now completely submerged by the Los Angeles Metropolitan Water District lake; the other at Pasadena, California, which was abandoned when the land was subdivided for residences.

#### CHERIMOYA

**Bays.**—Originated on the James H. Bays ranch in Ventura, California. Introduced commercially in 1920. Parentage unknown. Fruit: round; finger-printed surface; quality good. Tree: good bearer.

*Dr. White.*—See *White*.

**Sallmon.**—Originated in Chula Vista, California, by J. Eliot Coit. Introduced commercially in 1931. Seeds came from the William Sallmon ranch; Parentage unknown. Fruit: large; skin smooth and tough; quality poor. No longer being planted.

**White (Dr. White).**—Originated on the Dr. White ranch, Lemon Grove, California, by James H. Macpherson. Introduced commercially in 1930. Par-

entage unknown; discovered in 1928 from a tree planted in 1912. Fruit: large; flavor fine, even after fruit is quite soft.

#### CHERRY

**August Supreme.**—Originated in Wayne County, Ohio, by Menno Gerber. Introduced commercially in 1936. Patent no. 164; January 21, 1936; assigned to W. N. Scarff's Sons, New Carlisle, Ohio. Parentage unknown; discovered in 1932. Fruit: sweet; ripens very late, August 1 to 15 in region of origin; firm; juicy; juice does not exude when the stem is removed.

**Ebony.**—Originated in Moscow, Idaho, by the Idaho Agricultural Experiment Station (Leif Verner). Introduced commercially in 1946. Lambert x Black Republican (probably); selected in 1940. Fruit: good dessert quality; most nearly resembles Black Republican. Tree: bears heavily.

**Lamida.**—Originated in Moscow, Idaho, by the Idaho Agricultural Experiment Station (Leif Verner). Introduced commercially in 1946. Open pollinated seedling of Lambert; selected in 1940. Fruit: resists cracking; large; good dessert quality; most nearly resembles Lambert.

**Spalding.**—Originated in Moscow, Idaho, by the Idaho Agricultural Experiment Station (Leif Verner). Introduced commercially in 1946. Bing x Deacon (probably); selected in 1942. Fruit: large; very firm; good luster; most nearly resembles Bing.

#### CHESTNUT

**Abundance.**—Originated in Eagle Creek, Oregon, by Carroll D. Bush. Introduced commercially in 1941. Parentage: scions were cut from most vigorous seedlings resulting from planting of imported seed of *Castanea mollissima*. Nut: appearance attractive; cleans well; sweet; larger and more prolific than Honan which it most nearly resembles.

**Connecticut Yankee.**—See Yankee.

**Stoke (Stoke Hybrid).**—Originated in Roanoke, Virginia, by H. F. Stoke from mixed seed sent to him for stock purposes by the Division of Forest Pathology, U. S. Plant Industry Station, Beltsville, Maryland. The seed was produced at the Plant Propagating Garden (Bell Station), Glenn Dale, Maryland. Introduced commercially by Mr. Stoke in 1936. Parentage largely or altogether Japanese, although possibly part Chinese. Nut: ripens at Roanoke very early, usually beginning during the third week in August. Tree: extremely precocious; prolific; little else to commend it. Probably obsolete.

**Stoke Hybrid.**—See Stoke.

**Yankee (Connecticut Yankee).**—Originated in Riverside, Connecticut, on land now owned by E. E. Hunt; first propagated by Dr. J. Russell Smith, Swarthmore, Pennsylvania, in the Sunny Ridge Nurseries of northern Virginia in 1935. Introduced commercially in 1935. Parentage unknown, but probably indirectly from the United States Department of Agriculture. Nut: choice. Tree: hardy in eastern United States; *Castanea mollissima*.

**Zimmerman.**—Originated in Linglestown, Pennsylvania, by Dr. G. A. Zimmerman. Introduced commercially in 1935. Grown as a nursery seedling resulting from nuts (*Castanea mollissima*) imported from Nanking; selected in 1930; first propagated by H. F. Stoke, Roanoke, Virginia, in 1933; first catalogued by Dr. J. Russell Smith in 1938. Nut: appearance attractive; cleaning quality good; sweet; trifle small; may be supplanted by other varieties that have larger fruits.

#### CURRENT

**Red Lake.**—Originated in Excelsior, Minnesota, by the Minnesota Agricultural Experiment Station (W. H. Alderman). Introduced commercially in 1933. Parentage unknown. Fruit: large berries equal to those of Perfection; clusters long and well-filled. Bush: superior to those of the Perfection variety.

**Holländische Rote.**—See Viking.

**Rød Hollandsk Druerips.**—See Viking.

**Viking (Holländische Rote, Rød Hollandsk Druerips).**—Originated in Europe where it has been known for many years. Introduced commercially

in the United States of America from Norway by the United States Department of Agriculture (Glenn Gardner Hahn). *Ribes petraeum* Wulf. x *R. rubrum* L. (direction of cross not known). Fruit: red; matures late. Plant: immune to white pine blister rust (*Cronartium ribicola*); productive; only red currant grown in white pine territory [according to Dr. W. H. Alderman, University of Minnesota (1945)].

#### DATE

**Sphinx.**—Origin unknown; imported as Hayany into the United States in 1920 by the Phoenix Date Company, Phoenix, Arizona. Introduced commercially in 1925. Open pollinated seedling, supposedly of Hayany; selected in 1920. Fruit: small seed and very little rag; most nearly resembles Maktoon, except in color. Tree: very heavy producer (four-year record of 350 pounds per palm).

#### FILBERT

**Fitzgerald.**—Originated in Washougal, Washington, by D. Fitzgerald. Introduced commercially in 1936. Parentage unknown; open-pollinated seedling; discovered in 1936. Fruit: round type; good size.

#### GOOSEBERRY

**Pixwell.**—Originated in Fargo, North Dakota, by the North Dakota Agricultural Experiment Station (A. F. Yeager). Introduced commercially in 1932. Oregon Champion x *Ribes missouriense*; cross of 1920. Fruit: size medium; pink when ripe; in clusters and borne on long pedicels; few thorns. Bush: hardy; very productive.

#### GRAPE

**Brownie.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (J. G. Woodroof). Introduced commercially in 1933. Open pollinated seedling of San Monta; selected in 1930. Fruit: highest sugar content of muscadine varieties, quality excellent. Not recommended for commercial planting by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Burgaw.**—Originated in Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Thomas x V19 R7 B2 (Scuppernong x male); selected from a cross made about 1912. Vine: muscadine type; can be used as a pollinator; perfect-flowered; self- and cross-fertile; most nearly resembles Thomas.

**Cape Fear.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Burgaw x V20 R36 B4 [V19 R7 B2 (Scuppernong x male) x Kilgore]; cross made about 1915 or 1916. Fruit: muscadine type; color white; matures very late; most nearly resembles Scuppernong. Vine: pistillate variety.

**Cardinal.**—Originated in Fresno, California, by the United States Department of Agriculture (Elmer Snyder and Frank N. Harmon). Introduced commercially in October, 1946. Flame Tokay x Ribier (Alphonse Lavallée); selected in 1943. Fruit: matures early; quality good; most nearly resembles Ribier except for red color.

**Creek.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (J. G. Woodroof). Introduced commercially in 1938. Open pollinated seedling of San Monta; selected in 1934. Fruit: thinnest skin and highest percentage of free run juice of muscadine varieties; high in sugar and acidity; ripens late; recommended for commercial planting in southern half of muscadine region by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Creswell.**—Originated in eastern North Carolina by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing) of Willard, North Carolina. Introduced com-

mercially in 1946. Parentage unknown; discovered about 1915. Fruit: muscadine type; fine flavor; ripens over a long period. For home use.

**Dawn.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (H. P. Stuckey). Introduced commercially in 1938. Scuppernong x black male muscadine; selected in 1937. Fruit: earliest ripening variety; most nearly resembles Scuppernong. Not recommended by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Delight.**—Originated in Davis, California, by the California Agricultural Experiment Station (H. P. Olmo). Introduced commercially in the spring of 1947. Scolokertek hiralynojé No. 26 x Sultanina marble; cross made in 1936; first fruited in 1940. Fruit: seedless, oval, yellow-green, firm; cluster large, shouldered; well-filled; most nearly resembles Thompson Seedless but ripens 10 days earlier, shatters less, and in most localities has a slight Muscat flavor. Vine: fruitful when spur pruned. A table and raisin variety.

**Dulcet.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (J. G. Woodroof). Introduced commercially in 1934. Open pollinated seedling of Irene; selected in 1928. Fruit: excellent quality, persistent; most nearly resembles Thomas. Vine: foliage very resistant to black rot. Recommended for the home vineyard by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Duplin.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Stanford x V10 R15 B4 [Eden x V23 R4 B2 (Eden x Munsoniana)]; cross made about 1912. Fruit: muscadine type; large; black; clusters fair; most nearly resembles James. Vine: perfect flowered type for pollination purposes.

**Hanover.**—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (S. A. Beach). Introduced commercially in 1924. Brighton x Niagara; selected at Fredonia, New York, by F. E. Gladwin, October 3, 1924. Fruit: fruit quality holds longer than that of either parent; has promise for dessert and white wine; most nearly resembles Brighton in fruit characters. Vine: more vigorous and productive than either parent; more hardy than Niagara; flowers are self-fruitful.

**Howard.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (H. P. Stuckey). Introduced commercially in 1929. Scuppernong x black male muscadine; selected in 1926. Fruit: resembles Scuppernong. Not recommended by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Hunt.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (H. P. Stuckey). Introduced commercially in 1920. Flowers x white male muscadine; selected in 1918. Fruit: quality excellent; very even in ripening, unusual in muscadine grapes; dull black with little bloom when prime ripe; skin medium to thin with abundant pigment prized by manufacturers of wine and frozen pulp; sugar content higher than Scuppernong variety, containing appreciable amount of sucrose. Vine: very prolific. Considered the best dark fruiting variety, the only one unanimously recommended for commercial plantings in the southeastern states by the Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Interlaken Seedless.**—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (A. B. Stout, G. D. Oberle, and R. Wellington). Introduced commercially September 17, 1946. Ontario x Sultanina; selected September 6, 1937. Fruit: seedless; non-slipskin type; flesh crisp and meaty; most nearly resembles Sultanina but has slight Ontario flavor. Vine: seems to be sufficiently hardy for the eastern United States.

**Irene.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (H. P. Stuckey). Introduced commercially in 1920. Thomas x black male muscadine; selected in 1918. Not recommended by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Italia.**—Originated in Rome, Italy, by the Institute of Fruit Culture (A. Pirovano). Introduced commercially in California by the California Agricultural Experiment Station in 1946. Bicané x Muscat Hamburg; cross made in 1911. Fruit: berries very large, golden, with Muscat flavor; cluster loose, conical. Vine: very productive.

**Kilgore.**—Originated at the North Carolina Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Open pollinated seedling of Labama; cross of 1908. Fruit: muscadine type; flesh melting; seeds separate from pulp; flavor fair. Vine: weak.

**Lucida.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (J. G. Woodroof). Introduced commercially in 1933. Open pollinated seedling of Irene; selected in 1930. Fruit: largest bronze colored variety. Not recommended by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Melton.**—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced commercially in 1923. Triumph x New York Station Seedling #4064 [(Winchell x Diamond) x Jefferson]. Fruit: clusters long and attractive; quality good; texture good. This variety was dropped from the list recommended for trial for New York because of the tendency of the berries to crack during ripening.

**Morrison.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Scuppernong x a selected white male; cross made in 1909. Fruit: muscadine type; quality good; matures early; most nearly resembles Scuppernong. Vine: pistillate; growth weak.

**Myakka.**—Originated in southern Florida by Joseph L. Fennell. Introduced commercially in 1947. (*Vitis shuttleworthii* x *V. smalliana*) x *V. vinifera* hort. var. Malaga; selected in 1943. Fruit: clusters large; sweet flavored; purple skin; most nearly resembles Sultana except for purple color. Vine: productivity high; vigorous; moderate disease resistance; for semi-tropical conditions.

**Nevermiss.**—Originated in Gay, Meriwether County, Georgia, by M. Aubrey Owen. Introduced commercially in 1945. Patent no. 692; May 28, 1946; assigned to H. G. Hastings Company. Fruit: muscadine type; color white or bronze; sugar content high; cluster size much better than Scuppernong which it most nearly resembles. Vine: production regular; resistant to disease.

**New River.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Open pollinated seedling of San Jacinto; 1908 seedling. Fruit: muscadine type; white; matures early; most nearly resembles Scuppernong. Vine: a pistillate variety.

**November.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (H. P. Stuckey). Introduced commercially in 1920. Scuppernong x black male muscadine; selected in 1918. Not recommended by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Onslow.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. V22 R5 B4 (Scuppernong x male) x Burgaw; cross made about 1916. Fruit: muscadine type; black; clusters fair to good; most nearly resembles James. Vine: pistillate.

**Orton.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Latham x Burgaw; cross made about 1915. Fruit: muscadine type; sweeter than Scuppernong which it most nearly resembles. Vine: better foliage than Scuppernong; a pistillate variety.

**Pender.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Latham x V20 R36 B4 [Kilgore x V19 R7 B2 (Scuppernong x male)]; cross made about 1917. Fruit: muscadine type; white to yellowish; apple-flavored. Vine: perfect flowered for pollination purposes; most nearly resembles Scuppernong.

**Qualitas.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (H. P. Stuckey). Introduced commercially in 1920. Thomas x black male muscadine; selected in 1918. Not recommended by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Schuyler.**—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington and G. D. Oberle). Introduced commercially September 17, 1946. Zinfandel x Ontario; selected in 1932. Fruit: a hybrid which has much of the flavor and flesh characteristics of a vinifera grape; resembles Zinfandel more than it does Ontario. Vine: appears to be sufficiently hardy and disease resistant to be adapted to the climate of the eastern United States.

**Seminole.**—Originated in southern Florida by Joseph L. Fennell. Introduced commercially in 1947. (*Vitis shuttleworthii* x *V. rufo-tomentosa*) x (*V. candicans* x Rommel); selected in 1945. Vine: flowers perfect; vigorous, productive, and disease resistant in semi-tropical climate; most nearly resembles Catawba or Extra.

**Spalding.**—Originated at Experiment, Georgia, by the Georgia Agricultural Experiment Station (H. P. Stuckey). Introduced commercially in 1920. Flowers x white male muscadine; selected in 1918. Not recommended by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science.

**Stanford.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Open pollinated seedling of San Jacinto; selected about 1910. Fruit: muscadine type; white; large. Vine: pistillate; most nearly resembles Scuppernong.

**Steuben.**—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington and G. D. Oberle). Introduced commercially September 17, 1946. Wayne x Sheridan; selected October 5, 1937. Fruit: sugar content high; quality high; skin tough; keeping quality good; berry resembles Wayne; cluster resembles Sheridan; flavor resembles Eumelan. Vine: production heavy; resistant to black rot and downy mildew; winter hardiness.

**Stuckey.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (H. P. Stuckey). Introduced commercially in 1920. Scuppernong x black male muscadine; selected in 1918. Fruit: excellent quality. Not recommended by Muscadine Grape Committee, Southern Section, American Society for Horticultural Science due to low yields, weak growth, and susceptibility of foliage to black rot.

**Tarheel.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Luola x V36 R15 B4 [Eden x V23 R4 B2 (Eden x Munsoniana)]; selected from a cross made about 1912. Vine: muscadine type; variety for use as a pollinator; perfect flowered; self- and cross-fertile; most nearly resembles Eden.

**Topsail.**—Originated at the North Carolina Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Latham x Burgaw; selected from a cross made about 1915. Fruit: muscadine type; large and sweeter than Scuppernong which it most nearly resembles. Vine: more vigorous than Scuppernong.

**Van Buren.**—Originated in Fredonia, New York, by the Vineyard Laboratory of the New York State Agricultural Experiment Station (F. E. Gladwin). Introduced commercially in 1935. Fredonia x Worden. Fruit: quality of unfermented juice excellent; table quality good; skin is tender like that of Worden which it most nearly resembles in all fruit characters except berry size; susceptible to downy mildew. Vine: vigorous; winter hardy; productive; very early ripening season.

**Wallace.**—Originated at the Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Selection V26 R5 B4 (Scuppernong x male) x Willard; cross made about 1915. Vine: muscadine type; a pollinator variety; perfect flowered; self- and cross-fertile; most nearly resembles Scuppernong.

**Watkins.**—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced commercially in 1930. Mills x Ontario; first fruited in 1915. Fruit: quality outstanding; most nearly resembles Mills in flavor, texture, and quality. Variety no longer recommended for planting in New York because of its unreliable productivity and lack of hardness.

**Wayne.**—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced commercially in 1927. Mills x Ontario; first fruited in 1916. Fruit: most nearly resembles Mills in flavor, color, texture, and quality; its quality, texture, and flavor are more nearly viniferous than most varieties of its period of introduction. Variety has been dropped for plantings in New York because of its late season, its tendency to shell, and its unreliable productivity.

**Westfield.**—Originated in Fredonia, New York, at the Vineyard Laboratory of the New York State Agricultural Experiment Station (F. E. Gladwin). Introduced commercially in 1935. Herbert x Concord Seedless. Fruit: labrusca type, slipskin; skin blue; pigment content high which was considered valuable from the standpoint of use in blending in the making of wines and unfermented juices.

**Willard.**—Originated at the North Carolina Coastal Plains Experiment Station, Willard, North Carolina, by the United States Department of Agriculture and the North Carolina Department of Agriculture (Charles Dearing). Introduced commercially in 1946. Stanford x V19 R7 B2 (Scuppernong x male); selected from a cross made about 1910. Vine: muscadine type; for use as a pollinator; perfect-flowered; self- and cross-fertile; most nearly resembles Scuppernong.

**Yuga.**—Originated in Experiment, Georgia, by the Georgia Agricultural Experiment Station (J. G. Woodroof). Introduced commercially in 1934. Open pollinated seedling of San Monta; selected in 1932. Fruit: quality excellent; sweet; thin reddish-bronze skin. For the home vineyard. Not recommended for commercial plantings by Muscadine Grape Committee due to late and uneven ripening.

#### HICKORY

**Murdock.**—Originated in Crown Point, New York, by John Murdock. Introduced commercially about 1940. Parentage unknown; shagbark, probably discovered as a chance seedling, about 1936. Nut: quality high. Tree: hardy; bears early.

#### LEMON

**Pink-Fleshed (Variegated).**—Originated in San Fernando, California, by a Mr. Field of Brocton, Massachusetts, and first propagated by A. D. Shamel. Introduced commercially in December, 1937. Bud mutation of Eureka; discovered in 1935. Fruit: flesh and juice pink; rind variegated white, yellow, and green. Tree: foliage variegated; flowers pink. A plant novelty.

*Variegated.*—See Pink-Fleshed.

#### NECTARINE

**Burbank's Fuzzless.**—See Flaming Gold.

**Flaming Gold (Fuzzless, Burbank's Fuzzless).**—Originated in Sebastopol,



California, by Luther Burbank. Introduced commercially in 1928. Trademarked by Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; selected about 1916. Fruit: flesh yellow; freestone; skin smooth and red blushed; ripens before Elberta season.

*Fuzzless*.—See *Flaming Gold*.

**Fuzzless-Berta**.—Originated in Blacksburg, Virginia, by Frederick W. Hofmann. Introduced commercially in 1942. Patent no. 479; July 22, 1941. Parentage unknown, but probably an  $F_2$  segregate of a cross between peach and nectarine. Fruit: flesh yellow; freestone; similar to Elberta except for glabrous skin; quality fair. Tree: only moderate vigor; blossoms large, showy, light pink.

#### PEACH

**Davidson** (*Redleaf, Tennessee Redleaf*).—Found growing on a roadside in southwest Davidson County, Tennessee, by Joseph C. McDaniel. Introduced commercially in 1946 by Peach Ridge Farm, Clemson, South Carolina. Parentage unknown; discovered and first propagated in 1938. Fruit: flesh yellow; freestone; poor edible quality; pits give high germination without special treatment, many double kernels; for use as a rootstock variety. Most of the seedlings are red-leafed, vigorous, and well adapted to June or dormant budding.

**Elberta Queen**.—Originated in Louisiana, Missouri, by Gus Jordan. Introduced commercially in 1925. Bud mutation of Elberta; discovered in 1902. Fruit: flesh yellow; freestone; an Elberta selection that has fruit of a rounder shape and is somewhat larger than the parent.

**Elliott Special**.—Originated in Modesto, California, by William C. Elliott. Introduced commercially about 1940. Patent no. 166; February 18, 1936; unassigned. Open pollinated seedling of Lovell. Fruit: flesh yellow; freestone; matures late.

**Frankie**.—Originated in Marble Falls, Texas, by Kirk Schroeter. Introduced commercially in 1938. Thought to be a mutation of Frank; discovered in 1936. Fruit: flesh yellow; freestone; slightly red around the pit. Tree: prolific bearer; adapted to mild winter climate. Closely resembles Frank.

**Golden Elberta Cling**.—Originated in Fort Smith, Arkansas, by Will R. Gaunaway. Introduced commercially in 1925. Trademarked in 1925 by Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; discovered in 1911. Fruit: flesh yellow; clingstone; ripens 5 days before Elberta; most nearly resembles Early Elberta.

**Halate**.—Originated in the test orchard of Stark Brothers Nurseries, Louisiana, Missouri. Introduced commercially in 1937. Parentage unknown; discovered in 1924. Fruit: flesh yellow; freestone; ripens 2 weeks after Elberta; most nearly resembles J. H. Hale.

**Hal-Berta Giant**.—Originated near Xenia, Clay County, Illinois, by J. E. Markham. Introduced commercially in 1932. Patent no. 7; February 16, 1932; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; discovered in 1928. Fruit: flesh yellow; freestone; very large; skin smooth; matures in J. H. Hale season. Tree: hardy; bears well.

**Hardy-Berta**.—Originated near Mount Vernon, Jefferson County, Illinois, by Marsh Harpole. Introduced commercially in 1934. Patent no. 271; February 15, 1938; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; discovered in 1932. Fruit: flesh yellow; freestone; ripens 2 weeks after Elberta, which it most nearly resembles.

*Illinois K40*.—See *Prairie Schooner*.

*Illinois K43*.—See *Prairie Rambler*.

*Illinois K47*.—See *Prairie Clipper*.

*Illinois K69*.—See *Prairie Daybreak*.

*Illinois K73*.—See *Prairie Dawn*.

*Illinois K74*.—See *Prairie Sunrise*.

*Illinois K80*.—See *Prairie Rose*.

**July Elberta**.—Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1930. Patent no. 15; April 15, 1932; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown. Fruit: flesh yellow; freestone; highly colored; pit small; ripens before Elberta.

**July Gold.**—Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1930. Parentage unknown; selected in 1928. Fruit: flesh orange; freestone; no red at pit. Tree: very hardy.

**Meadow Lark.**—Originated in Ontario, California, by Walter E. Lammerts. Introduced commercially in 1947. Patent no. 528; June 30, 1942; assigned to Armstrong Nurseries, Inc., Ontario, California. (Early Imperial x Coolidge Double Red) x Socala; selected in 1941. Fruit: superficially most nearly resembles Elberta. Tree: sufficiently low chilling requirement to be well suited to growing in southern California, being about one grade better than Babcock in this respect.

**Missouri.**—Originated in Mountain Grove, Missouri, by the Missouri State Fruit Experiment Station (Paul H. Shepard). Introduced commercially in 1946. Open-pollinated seedling of Sunbeam; selected in 1942. Fruit: round, larger than Sunbeam; flesh yellow, firm, good flavor; red blushed skin, fuzz short; clingstone, small pit, ripens 4 to 5 weeks before Elberta. Resembles Tuskena in outward appearance.

**Ozark.**—Originated in Mountain Grove, Missouri, by the Missouri State Fruit Experiment Station (Paul H. Shepard). Introduced commercially in 1946. Frank x Halehaven; selected in 1943. Fruit: flesh yellow, freestone, large, full red skin color, firm, ripens 2 weeks before Elberta. Tree: hardy. Fruit most nearly resembles J. H. Hale.

**Prairie Clipper (Illinois K47).**—Originated in the Horticultural Farm, Olney, Illinois, by the Illinois Agricultural Experiment Station (M. J. Dorsey). Introduced commercially in 1946. J. H. Hale x Gage; cross made in 1933. Fruit: very large, medium yellow with dark red blush, dull appearance; flesh yellow, deeper color at stone, firm J. H. Hale type of flesh; quality good, flavor sharp; freestone; ripens 3 days before Elberta.

**Prairie Dawn (Illinois K73).**—Originated in the Horticultural Farm, Olney, Illinois, by the Illinois Agricultural Experiment Station (M. J. Dorsey). Introduced commercially in 1946. Valiant x Halehaven; cross made in 1937. Fruit: medium to large, medium yellow, light red blush, attractive; flesh medium yellow, tender, juicy; freestone when fully mature. Ripens 40 days before Elberta. Fruit buds harder than Elberta.

**Prairie Daybreak (Illinois K69).**—Originated in the Horticultural Farm, Olney, Illinois, by the Illinois Agricultural Experiment Station (M. J. Dorsey). Introduced commercially in 1946. Halehaven x Sun Glo; cross made in 1937. Fruit: large, oval; medium yellow, dark red blush, dull appearance; flesh light yellow, tender, firm, moderately juicy, freestone. Ripens 37 days before Elberta.

**Prairie Rambler (Illinois K43).**—Originated in the Horticultural Farm, Olney, Illinois, by the Illinois Agricultural Experiment Station (M. J. Dorsey). Introduced commercially in 1946. Elberta x Gage; cross made in 1933. Fruit: very large, greenish yellow, light to dark red blush, attractive; flesh yellow with some red at stone, firm, juicy, sub-acid, spicy flavor; freestone. Ripens 3 days after Elberta.

**Prairie Rose (Illinois K80).**—Originated in the Horticultural Farm, Olney, Illinois, by the Illinois Agricultural Experiment Station (M. J. Dorsey). Introduced commercially in 1946. Gage x Halehaven; cross made in 1937. Fruit: medium to large, round, medium yellow, blushed and splashed with dark red, very attractive; flesh, medium yellow with occasional trace of red through flesh and at stone, medium firm, juicy; freestone. Ripens 25 days before Elberta.

**Prairie Schooner (Illinois K40).**—Originated in the Horticultural Farm, Olney, Illinois, by the Illinois Agricultural Experiment Station (M. J. Dorsey). Introduced commercially in 1946. Elberta x South Haven; cross made in 1933. Fruit: large, oval, light yellow, light red blush; flesh light yellow, lighter color at stone, tender, juicy; semi-cling until fully mature; ripens 21 days before Elberta. Inclined to overset.

**Prairie Sunrise (Illinois K74).**—Originated in the Horticultural Farm, Olney, Illinois, by the Illinois Agricultural Experiment Station (M. J. Dorsey). Introduced commercially in 1946. Valiant x Halehaven; cross

made in 1937. Fruit: large, round, medium yellow, dark red blush, attractive; flesh medium yellow, tender, juicy; semi-cling until fully mature. Ripens 37 days before Elberta.

*Redleaf*.—See Davidson.

*Socala*.—Originated in Ontario, California, by Mrs. C. C. Barnes. Introduced commercially about 1942. Parentage unknown; discovered about 1935. Fruit: matures earlier than July Elberta, which it most nearly resembles, in southern California. Tree: requires less winter chilling than other varieties of the July Elberta type and season.

*Southland*.—Originated in Fort Valley, Georgia, by the United States Department of Agriculture (J. H. Weinberger). Introduced commercially July 15, 1946. Halehaven x self; selected in June, 1939. Fruit: flesh yellow; freestone; large; ripens with Hiley; firmer, slower softening flesh and more attractive color than Halehaven which it most nearly resembles.

*Starks Sure Crop*.—Originated in Ash Grove, Missouri, by John W. Nicholson. Introduced commercially in 1946. Patent no. 670; January 15, 1946; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Open pollinated seedling of Greensboro. Fruit: flesh white; clingstone; matures very early. Tree: hardy; regular cropper under adverse conditions.

*Tennessee Redleaf*.—See Davidson.

*Texaberta*.—Originated in Belton, Texas, by E. E. Griffith. Introduced commercially in 1938. Parentage unknown; discovered in 1936. Fruit: flesh yellow; freestone; slightly red around the pit; most nearly resembles Elberta. Tree: requires less chilling than Elberta.

*Wahlbert*.—Originated in Clarkston, Washington, by Albert W. Wahl. Introduced commercially in 1942. Patent no. 520; May 26, 1942; assigned to H. Lynn Tuttle, Clarkston, Washington. Parentage unknown; first observed in 1918 and propagated in 1935. Fruit: flesh yellow; freestone; firm; handles and ships well; matures two weeks earlier than J. H. Hale which it most nearly resembles.

*World's Earliest*.—Originated in Moscow, Tennessee by E. L. Morris. Introduced commercially in 1936. Trademarked by Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; discovered in 1933. Fruit: flesh white; clingstone; ripens early; most nearly resembles Red Bird.

#### PEAR

*Richard Peters*.—Originated in State College, Pennsylvania, by the Pennsylvania Chain Store Council (E. L. Nixon). Introduced commercially in 1927. Probably an open pollinated seedling of Kieffer; selected in 1924. Fruit: most nearly resembles Bartlett. Tree: practically immune to fire blight; vigorous grower.

#### PECAN

*John Garner*.—Originated in San Saba, Texas, by E. E. Risen. Introduced commercially in 1934. San Saba Improved x Onliwon; selected in 1933. Nut: shell thin; large; attractive appearance; most nearly resembles Burkett. Tree: vigorous; prolific bearer.

*Select*.—Originated in Riverside, California, by Robert Halsey Harris. Introduced commercially in 1943. Patent no. 510; March 28, 1942; assigned to Lawrence Sherwood, Sherwood Specialty Nursery, Fullerton, California. Open pollinated seedling of Altman. Nut: shell thin; fills well; large; matures in early fall. Tree: exceptionally heavy bearer; starts bearing at an early age; vigorous grower; wide climatic adaptability.

#### PLUM

*Algoma (0-302)*.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced for trial in 1937. Sand cherry (*Prunus besseyi*) x Burbank; selected in 1935. Fruit: good size and quality for a plum of this type; intermediate between the sand cherry and the plum. Tree: extremely hardy; bushy habit; early bearing.

*Hollywood*.—Originated in Modesto, California, by L. L. Brooks. Intro-

duced commercially in 1936. *Prunus pissardi* x *P. salicina* (direction of cross unknown); discovered about 1932; first commercially propagated by Ralph S. Moore, Visalia, California. Fruit: flesh red, like a giant cherry; ripens early, in Beauty season; used for jelly and canning; most nearly resembles Satsuma. Tree: most nearly resembles *Prunus pissardi*.

**Howard Miracle.**—Originated in Montebello, California, by Frederick H. Howard. Introduced commercially in 1947. Patent no. 721; December 31, 1946; assigned to Howard and Smith, Montebello, California. Parentage unknown; discovered about 1941. Fruit: Japanese type; large, flesh firm; matures late in August in the vicinity of Montebello; flavor very good and distinctive; ships well. Tree: needs cross-pollination.

**Monitor.**—Originated in Excelsior, Minnesota, by the Minnesota Agricultural Experiment Station (W. H. Alderman). Introduced commercially in 1920. Burbank x a native American plum; first fruited in 1918. Fruit: medium to large; roundish-ovate; dull bronze-red; quality good; clingstone; cracks in rainy weather. Tree: vigorous; very hardy; productive.

0-302.—See *Algoma*.

#### RASPBERRY

**Dike.**—Originated in Bristol, Vermont, by A. C. Dike. Introduced commercially about 1926. Latham x Cuthbert. Fruit: red; color good; quality good. Bush: hardy, resistant to mosaic.

**Dixie.**—Originated in Raleigh, North Carolina, by the North Carolina Agricultural Experiment Station (Carlos F. Williams). Introduced commercially in 1938. *Rubus biflorus* x Latham; selected from a cross made in 1928. Fruit: red; size medium; tart. Bush: vigorous, productive; disease resistant; adapted to southeastern states south of the region of American red raspberries thus far produced; most nearly resembles a hybrid with Asiatic species.

**Durham.**—Originated in Durham, New Hampshire, by the New Hampshire Agricultural Experiment Station (A. F. Yeager). Introduced commercially in 1947. Taylor x Nectar blackberry; cross attempted in greenhouse but the seedling is probably a parthenogenetic seed therefrom; selected in 1944. Fruit: red; firm; medium size; fall bearing, beginning to ripen 2 weeks before the fall crop of Indian Summer, hence a worthwhile crop in autumn.

*Honeysweet* (of New Jersey).—See *Yellow Honeysweet*.

*Morris*.—See *Morrison*.

**Morrison (Morris).**—Originated in North Kingsville, Ohio, by Fred Morris. Introduced commercially in 1942. Parentage unknown; discovered about 1925. Fruit: black; large; attractive; season late; most nearly resembles Cumberland.

**Ruddy.**—Originated in Fargo, North Dakota, by the North Dakota Agricultural Experiment Station (A. F. Yeager). Introduced commercially in 1937. Selected  $F_2$  seedling (Plum Farmer x Latham); selected in 1933. Fruit: purple. Bush: produces well; reproduces by suckers as do the red varieties; resistant to red spider; very hardy.

**Sunrise.**—Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1939. Latham x Ranere; selected in 1923. Fruit: red; matures very early, 2 days before Ranere and nearly 2 weeks before Latham; quality better than Latham; size intermediate between Ranere and Latham; texture fine; does not crumble; picks easily. Bush: resistant to leaf spot and anthracnose; very hardy.

**Yellow Honeysweet** [*Honeysweet* (of New Jersey)].—An unidentified French variety introduced into the United States about 1925 by Bobbink and Atkins, East-Rutherford, New Jersey. Fruit: golden yellow color; flavor good.

#### STRAWBERRY

**Borden.**—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced for trial in 1936. (Nor J x Parsons Beauty) x (*Fragaria* sp. x Jessie); selected in 1934. Plant: very

productive; light runner; subject to drought. Variety grown only to a limited extent.

**Burgundy** (*Minnesota No. 1192*).—Originated in Excelsior, Minnesota, by the Minnesota Agricultural Experiment Station (A. N. Wilcox). Introduced commercially in 1943. Easypicker x Duluth; selected in 1929. Fruit: late; large; regular; somewhat pubescent; roundish cordate; dark red, evenly colored; rather glossy; achenes medium few and raised; flesh very dark red, firm, and meaty; flavor aromatic and subacid; quality very good. Plant: hardy, vigorous, upstanding; very productive; June-bearing; flowers late and pistillate, being 2 weeks later than Howard 17.

**Claribel**.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced for trial in 1935. Ettersburg 121 x Cassandra; selected in 1933. Fruit: very firm, fleshed; short fruit stalks; season very late; quality poor. Plant: imperfect flowers. Variety grown only to a limited extent.

**Fairpeake**.—Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George F. Waldo). Introduced commercially in 1944. Chesapeake x Fairfax; selected in 1933. Fruit: highly flavored; firm; matures very late. Plant: productive; very vigorous.

**Howe**.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced for trial in 1936. (Red Sugar x Howard 17) x (Willard x Santiago de Chile); selected in 1934. Fruit: large; appearance attractive; frequently rough. Plant: imperfect flowers. Variety grown only to a limited extent.

**Jim**.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced for trial in 1932. Open pollinated seedling of Willard; selected in 1931. Fruit: large; season early; too pale in color; soft fleshed. Variety grown only to a limited extent.

**John**.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced for trial in 1933. Open pollinated seedling of Willard; selected in 1931. Fruit: fairly attractive and productive. Variety grown only to a limited extent, giving way to better ones.

**Midland**.—Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George F. Waldo and George M. Darrow). Introduced commercially in 1944. Howard 17 x Redheart; selected in 1931. Fruit: large, firm, high flavor; matures early. Plant: productive.

*Minnesota No. 1192*.—See **Burgundy**.

**Simcoe**.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced for trial in 1936. (Red Sugar x Howard 17) x (Delecto x Cassandra); selected in 1934. Fruit: large; attractive; loses size after two or three pickings. Plant: imperfect flowered. Variety grown only to a limited extent.

**Wright**.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced for trial in 1936. (Portia x Ettersburg 512) x (Santiago de Chile x self); selected in 1934. Fruit: large; sugar content high; flavor flat. Plant: foliage leathery and thick; production poor. Variety grown only to a limited extent.

## WALNUT

**Grande**.—Originated in Mesilla Park, New Mexico, by the New Mexico Agricultural Experiment Station (Fabian Garcia). Introduced commercially in 1932. Open pollinated seedling of Franquette; selected in 1928. Nut: quality fine; most nearly resembles Mayette; Persian type. Tree: prolific bearer.

## WHITE SAPOTE

**Flournoy**.—Originated on the Flournoy ranch, El Cajon, California, by James H. Macpherson. Introduced commercially in 1930. Open pollinated seedling of Wilson; selected in 1928. Fruit: quality fine; most nearly resembles Wilson. Tree: bears heavily; hardy.

## NAMES OF PATENTED VARIETIES

<i>Patent Number</i>	<i>Varietal Name</i>
7	Hal-Berta Giant, peach
15	July Elberta, peach
39	Kosmos, blackberry
164	August Supreme, cherry
166	Elliott Special, peach
247	Olympic, blackberry
271	Hardy-Berta, peach
479	Fuzzless-Berta, nectarine
510	Select, pecan
520	Wahlbert, peach
528	Meadow Lark, peach
630	Bowers, apricot

<i>Patent Number</i>	<i>Varietal Name</i>
659	Etter's Gold, apple
670	Starks Sure Crop, peach
674	Earle Orange, apricot
692	Nevermiss, grape
693	Reeves, apricot
699	Alaska, apple
710	Jonwin, apple
720	Redgold, apple
721	Howard Miracle, plum
722	Frostproof, apple
723	Pink Pearl, apple

## ALPHABETICAL LIST OF VARIETY NAMES

## INCLUDED IN LIST NO. 3

Abundance, chestnut  
 Alaska, apple  
 Algoma, plum  
 Atha, apple  
 August Supreme, cherry  
 Bays, cherimoya  
 Big-Ness, blackberry  
 Borden, strawberry  
 Bowers, apricot  
 Burbank's Fuzzless, nectarine  
     See Flaming Gold  
 Burgundy, strawberry  
 Brownie, grape  
 Burgaw, grape  
 Cameron, blackberry  
 Cape Fear, grape  
 Cardinal, grape  
 Claribel, strawberry  
 Connecticut Yankee, chestnut.  
     See Yankee  
 Creek, grape  
 Creswell, grape  
 Dark-Red Staymared, apple  
 Davidson, peach  
 Dawn, grape  
 Delight, grape  
 Dike, raspberry  
 Dixie, raspberry  
 Dr. White, cherimoya.  
     See White  
 Dulcet, grape  
 Duplin, grape  
 Durham, raspberry  
 Earle Orange, apricot  
 Earli-Ness, blackberry  
 Ebony, cherry  
 Elberta Queen, peach  
 Elliott Special, peach  
 Etter's Gold, apple  
 Fairpeake, strawberry  
 Fitzgerald, filbert  
 Fireside, apple

Flaming Gold, nectarine  
 Flournoy, white sapote  
 Frankie, peach  
 Frostproof, apple  
 Fuzzless-Berta, nectarine  
 Fuzzless, nectarine  
     See Flaming Gold  
 Golden Elberta Cling, peach  
 Grande, walnut  
 Hardy-Berta, peach  
 Hal-Berta Giant, peach  
 Halate, peach  
 Hanover, grape  
 Honeysweet (of New Jersey), rasp-  
     berry. See Yellow Honeysweet  
 Holländische Rote, currant.  
     See Viking  
 Hollywood, plum  
 Howard, grape  
 Howard Miracle, plum  
 Howe, strawberry  
 Hunt, grape  
 Idagold, apple  
 Illinois K40, peach.  
     See Prairie Schooner  
 Illinois K43, peach.  
     See Prairie Rambler  
 Illinois K47, peach.  
     See Prairie Clipper  
 Illinois K69, peach.  
     See Prairie Daybreak  
 Illinois K73, peach.  
     See Prairie Dawn  
 Illinois K74, peach.  
     See Prairie Sunrise  
 Illinois K80, peach.  
     See Prairie Rose  
 Interlaken Seedless, grape  
 Irene, grape  
 Italia, grape  
 Jim, strawberry  
 John, strawberry

- John Garner, pecan  
 Jonwin, apple  
 July Elberta, peach  
 July Gold, peach  
 Kilgore, grape  
 Kosmo, blackberry. See Kosmos  
 Kosmos, blackberry  
 Lamida, cherry  
 Lizakowsky, apple,  
     See Saint Clair  
 Lucida, grape  
 Margaret Pratt, apple  
 Meadow Lark, peach  
 Melton, grape  
 Midland, strawberry  
 Minnesota No. 396, apple.  
     See Victory  
 Minnesota No. 993, apple.  
     See Fireside  
 Minnesota No. 1192, strawberry.  
     See Burgundy  
 Missouri, peach  
 Monitor, plum  
 Morris, raspberry.  
     See Morrison  
 Morrison, grape  
 Morrison, raspberry  
 Murdock, hickory  
 Myakka, grape  
 Nevermiss, grape  
 New River, grape  
 November, grape  
 O-302, plum. See Algoma  
 Olympic, blackberry  
 Onslow, grape  
 Orton, grape  
 Ozark, peach  
 Payette, apple  
 Pender, grape  
 Phelps, apricot  
 Pink-Fleshed, lemon  
 Pink Pearl, apple  
 Pixwell, gooseberry  
 Prairie Clipper, peach  
 Prairie Dawn, peach  
 Prairie Daybreak, peach  
 Prairie Rambler, peach  
 Prairie Rose, peach  
 Prairie Schooner, peach  
 Prairie Sunrise, peach  
 Qualitas, grape  
 Red Delicious, apple.  
     See Redwin  
 Redgold, apple  
 Red Gravenstein, apple  
 Red Hackworth, apple  
 Red Lake, currant  
 Redleaf, peach. See Davidson  
 Redwin, apple  
 Reeves, apricot  
 Regal-Ness, blackberry  
 Richard Peters, pear  
 Rød Hollandsk Druerips, currant.  
     See Viking  
 Rome Beauty Double Red, apple  
 Ruddy, raspberry  
 Saint Clair, apple  
 Sallmon, cherimoya  
 Santa Fe, carob  
 Schuyler, grape  
 Select, pecan  
 Seminole, grape  
 Simcoe, strawberry  
 Socala, peach  
 Southland, peach  
 Spalding, cherry  
 Spaulding, grape  
 Sphinx, date  
 Stanford, grape  
 Starks Sure Crop, peach  
 Steuben, grape  
 Stoke, chestnut  
 Stoke Hybrid, chestnut.  
     See Stoke  
 Stuckey, grape  
 Sunrise, raspberry  
 Tarheel, grape  
 Tennessee Redleaf, peach.  
     See Davidson  
 Texaberta, peach  
 Texas R40-4, blackberry.  
     See Earli-Ness  
 Texas R40-51, blackberry.  
     See Big-Ness  
 Texas R40-202, blackberry.  
     See Regal-Ness  
 Topsail, grape  
 Van Buren, grape  
 Variegated, lemon.  
     See Pink-Fleshed  
 Victory, apple  
 Viking, currant  
 Wahlbert, peach  
 Wallace, grape  
 Watkins, grape  
 Wayne, grape  
 Wealthy Double Red, apple  
 Westfield, grape  
 White, cherimoya  
 Willard, grape  
 Willow Twig Double Red, apple  
 World's Earliest, peach  
 Wright, strawberry  
 Yankee, chestnut  
 Yellow Honeysweet, raspberry  
 Yuga, grape  
 Zimmerman, chestnut

## Research on Problems of Tung Production and Improvement, 1938-1946 (Presidential Address)

By GEORGE F. POTTER, *U. S. Department of Agriculture,  
Bogalusa, La.*

**A**LEURITES FORDII, the species of tung that is grown commercially in the United States, is indigenous to eastern Asia. The oil expressed from its seeds has been used by the Chinese for many centuries as an illuminant and for waterproofing. The culture of tung in the United States is a relatively new industry, tracing its origin to seeds imported from China by the Division of Plant Exploration and Introduction of the Bureau of Plant Industry, Soils, and Agricultural Engineering,<sup>1</sup> United States Department of Agriculture, beginning in 1904. The seeds were first planted in California, but it was in the acid soils of the well-watered coastal plain of the southeastern United States that the alien tree was found to thrive. A tree planted near Tallahassee, Florida, in November, 1906, by the late William H. Raynes, bore about 3 bushels of fruit in 1913, from which the first 2.2 gallons of American tung oil was expressed. American manufacturers were importing large quantities of this valuable drying oil for various industrial purposes, and members of the National Paint, Varnish, and Lacquer Association became interested in the possibility of obtaining a domestic supply. One manufacturer planted an extensive tung orchard and in 1928 built the first plant ever to process tung fruits with modern machinery. On March 17, 1932, the first tank car of domestic tung oil rolled to market from Gainesville, Florida.

Thousands of acres of cheap cut-over lands were available for planting and the culture of this exotic tree seemed to fire the imagination of persons in all walks of life — lumbermen, doctors, lawyers, school teachers, railroad men, dog-biscuit manufacturers, college students, and now and then some one possessed of a real horticultural background. By 1938 no less than 150,000 acres of tung orchard had been planted in an area extending from northern Florida and southern Georgia, across southern Alabama, Mississippi, and Louisiana, to southeastern Texas; and perhaps 1½ million pounds of oil were processed from the crop that year. It was an extensive development, considering the paucity of information on tung culture.

During the early years of the growth of the industry, the State agricultural experiment stations of the southeastern United States had devoted what funds they could spare to research on its problems. As early as 1924 Newell (37) published a report on experiments with tung oil at the Florida Agricultural Experiment Station. Early in the history of tung growing in Florida, a disorder, known as bronzing, threatened to destroy the orchards and it was only through the work of Mowry and Camp (35), who showed the trouble to be a deficiency of zinc, that the newborn industry survived. Reuther and Dickey (46) found another less serious trouble to be manganese deficiency, and

The writer is indebted to Dr. H. L. Crane and other members of the staff of Tung investigations for reviewing the manuscript, and to Paul Homeyer and Churchill Einsenhardt who have verified statements concerning biometry.

<sup>1</sup>Current bureau and division names are used throughout this paper.



more recently Dickey (7) has diagnosed a chlorosis due to iron deficiency and prescribed corrective measures. Abbott (1) made a fundamental study of blossom bud differentiation in tung and in 1930 a comprehensive publication on tung culture was published by Newell *et al* (38). In Georgia, Pickett and Brown (41) studied oil content of tung fruits and in Louisiana, Kimbrough and Miller (25) conducted very valuable studies on the fertilizer requirements of the tung tree. The experiment stations in most of the southeastern States issued circulars for the guidance of prospective tung growers. Mowry (34) and Blackmon (5) have reviewed the role of the experiment stations in the early development of the tung oil industry.

However, by 1938 tung growers realized that many costly mistakes were being made and that there was an immediate need of extensive investigational work on the requirements of the tung tree. In that year Congress first appropriated funds for research on tung to the United States Department of Agriculture. By agreement within the Department, the Bureau of Agricultural and Industrial Chemistry was given responsibility for problems having to do with processing of the crop and utilization of the products; the Bureau of Plant Industry, Soils, and Agricultural Engineering undertook, through its Division of Fruit and Vegetable Crops and Diseases, to investigate problems of production practices, breeding, and diseases. The work was placed under the direction of H. L. Crane, Project Leader for Nut Investigations, and of the late H. P. Gould, Division Chief, who was succeeded by J. R. Magness. The appropriations available have made it possible for the United States Department of Agriculture to play a major part in tung investigations since 1938, but the work of the State experiment stations has by no means been replaced. Rather, since 1938 all agencies have collaborated freely and many investigations have been conducted cooperatively, as in Florida. In Mississippi an experimental tung farm has been operated jointly.

To conduct the work in the Bureau of Plant Industry, Soils, and Agricultural Engineering a staff was recruited capable of focusing the techniques of several basic sciences on the problems of tung growing, including men trained in pomology, plant physiology, biochemistry, microscopy, soil technology, plant pathology, and genetics and plant breeding. Since 1941 war and economic factors have played havoc with the organization, yet today all the disciplines listed above with the single exception of microscopy are still represented on the staff. If cooperation can be fostered among the members of such a group, progress in research will far exceed the best possible through individual effort.

The men are stationed at four field laboratories located in the tung-growing centers of the South, and at Beltsville, Maryland, where fundamental studies of nutrition are conducted in the greenhouse. The organization is unique in that all of the work at the field laboratories is cooperative, either with the State experiment stations or with private tung growers. The Government does not own a single acre of tung orchard. This arrangement is not without disadvantages. Co-operators are handpicked, yet sometimes the crop on an experimental

plot is gathered before records have been made, and in a few instances a whole experimental set up has been lost through carelessness or neglect on the part of a grower-cooperator. The distance from the laboratory to the cooperator's plantation, is often 40, sometimes 50 or 60 miles. Staff members spend much time traveling back and forth, and the maintenance of automotive equipment is a considerable item of expense. On the other hand tremendous saving is effected in cost of maintaining experimental farms, and as a net result funds seem to go farther. Breeding plots alone at one of the laboratories comprise nearly 1,000 acres of orchard, far more than could have been financed on government appropriations. Of more importance is the stimulus of intimate day by day contact of our field men with the operators of commercial tung farms. There is no danger of becoming academic or of failing to take cognizance of the problems of the industry.

Yet perhaps the greatest advantage lies in the wide distribution of field experiments. In formulating recommendations from the results of experiments, horticulturists and workers in allied fields are prone to take it for granted that their plots constitute a representative random sample from the territory to which the conclusions are to be extended. Such an assumption is often unwarranted, when all the data are derived from plots on a single farm. In contrast, in a 3-year study now being completed on the mineral requirements of tung trees during their first season in the orchard, plots have been used on eleven different farms in two Louisiana parishes, and one Mississippi county, an area within which more than 40 per cent of the tung orchards of the United States are located. Rather complete coverage of the tung-producing regions is had from the four laboratories, located respectively in northeastern Florida, in southern Georgia, southern Alabama, and in eastern Louisiana, close to the Pearl River boundary. Variety trials, for example, are conducted on two to five farms in the vicinity of each laboratory. The integration of results from such widespread trials leads to a confidence in the conclusions that could not ensue from experiments conducted on a less representative basis.

It was the desire of Dr. E. C. Auchter, Chief of the Bureau of Plant Industry, Soils, and Agricultural Engineering in 1938, that tung investigations should not only serve the industry and to that end provide answers to the immediate practical problems of the grower, but that it should also carry on fundamental studies that would add to scientific knowledge and ultimately provide a foundation for a thorough understanding of the physiology of tung. In spite of the many difficulties incident to World War II, most of Dr. Auchter's requirements are being fulfilled. The more than one hundred publications that have been issued or are in preparation include, among those dealing with the more immediate practical problems, such topics as soils (8); stratification and germination of seed (51), nursery fertilization (32), budding of tung seedlings (31), transplanting (21), pruning and training (39), soil management and cover crops (43), effects of cultivation (22, 43), effects of mulch (40), nitrogen fertilizer effects (53), effects of fertilizers on oil content of tung fruit (4, 42), various mineral deficiencies (11, 12, 13), cold injury (15, 16), harvesting and

storage (17), tung diseases (24, 26), and one general publication on tung culture (20). Many of these, while classed as being of immediate practical value, are the end result of rather technical research. Further evidence that technical and fundamental research has not been neglected is afforded by papers dealing with chemical methods (9, 23), with chemical composition of developing tung fruits (49), with the isolation and identification of chemical constituents of the tree and its fruit (47, 48), with physical and chemical properties of tung soils (14), with leaf composition (10), with physiological effects of deficiencies (18), with the effects of various hormones on dormancy in tung buds (50), with photosynthesis (27), 45), with the morphology and embryology of tung fruit (28, 29), and with nutrient balance concept in plant nutrition (52). It is neither feasible nor desirable at this time to give a complete review of the progress made in these 8 years of research on tung. It seems better to summarize a few of the most important results using them mainly to illustrate the methods that have proved most effective in solving tung problems.

One of the outstanding needs of the industry is for improved varieties of tung trees. Commercial tung orchards of the South consist almost exclusively of seedling trees, which, as Mowry (33) was first to point out, are exceedingly variable. It is evident to the most casual observer that yields would be greatly increased if all trees were uniformly high in production. Mass selection had been practiced by some of the better growers prior to 1938, and at the Florida Experiment Station, two trees, the Florida 2 and the Florida 9, had been propagated by budding, and seedlings of both of them had been grown from open-pollinated seed. The resources of the Department of Agriculture permitted undertaking a simple, but rather extensive program of selection and breeding. During 1938 and 1939, 604 individual trees outstanding for high, regular production, for fruit of large size and high oil content, and for cold resistance and other desirable characteristics of the tree were selected in bearing orchards in the six tung-producing states, and their distinctive features were catalogued. Those judged most promising were propagated by budding, as a means of perpetuating the type.

In 1938 propagation of tung by budding was considered impractical by most growers and some experiment station authorities. Experience quickly demonstrated that cold injury was a major factor in the failures. This trouble was eliminated by budding in late summer when neither budsticks nor rootstocks had ever been exposed to cold and by banking the buds with earth in early fall to protect against low temperatures in the succeeding winter. Merrill (31) found that vigorous growth of the rootstock is also essential and good stands of excellent trees are now obtained readily with almost any budding technique. In general the budding trees have done well in the orchard, although they are more difficult to transplant than seedlings and on some rather dry sandy soils seem subject to physiological troubles from which seedlings are free. Recent evidence suggests that the rootstock may be of great importance in this connection. For example the average magnesium content, dry basis, of the leaves of six varieties of

tung trees was 0.20 per cent when budded on seedling rootstock designated F551 and was 0.32 per cent when budded on seedling rootstock designated G-40, a difference that has statistical significance at the 0.001 level. Records of production up to 5 or 6 years of age in numerous trial orchards would warrant the use of budded trees in most tung producing areas in preference to the rather heterogenous seedlings found in present bearing orchards.

However, in addition to budding, progenies from open-pollinated seed of each of the 604 selected trees were planted out in extensive trial orchards and, as has been reported by Angelo (2), a few outstanding seedling progenies have been found among the hundreds tested. The vast majority of seed parents give evidence of a heterozygous genetic constitution by producing exceedingly variable offspring even from controlled selfed seed. Yet a certain few seed parents produce remarkably uniform progenies from open-pollinated seed. Thus 25 trees from open-pollinated seed of the tree A-36 chanced to be planted at Folsom, Louisiana, alongside a row of budded trees of the variety M-1. Judged by tree type, crop production, and characteristics of the fruit, the seedling trees of A-36 are as uniform and true to their own type as are the budded trees of M-1. Two trees, designated L-46 and L-47, which stand so close together in the orchard that if cross-pollinated much the same pollen must be carried to both, produce two distinctive and rather uniform progenies from open-pollinated seed. Third generation trees from a so-called "McKee" tree in Folsom, Louisiana, to which attention was first directed by Gaston Lanaux, a private grower, constitute one of the most uniform orchards that the writer has ever seen. Some geneticists who have seen these trees and others to whom the results have been described think it probable that some form of apomixis takes place in these instances. It has not been possible to investigate this problem cytologically, but controlled crosses have been made that soon will determine whether any characteristics of the pollen parent appear in the offspring.

The only plausible explanation for the uniformity of the seedlings from certain parent trees, other than some form of apomixis, is that such trees are relatively homozygous and self-pollinated. With rare exceptions the tung tree is monoecious, and produces pistillate and staminate flowers in the same inflorescence. On the vast majority of trees the staminate flowers outnumber the pistillate by about 40 to 1. Dichogamy is unknown in tung; and in a relatively extensive program of controlled pollination work no instances of self-incompatibility have been found. Hence the possibility exists that sufficient self-pollination takes place to produce occasional individuals of rather homozygous genetic constitution.

Many growers are planting "second generation" seed from seedling selections such as the L-46 and L-47, which they procure from the grower-cooperators who own the trial orchards. More than 500,000 of these seedlings will be planted in commercial tung orchards during the early months of 1947. If these seedling selections are truly parthenogenetic, they will continue to give uniform offspring indefinitely; but if the genetic constitution which gives superiority to these seed

parents is changed through a process of fertilization, "second generation" seedling trees may be expected to be variable and certain of them to be inferior to the original parent. However, since we know that the vast majority of tung trees fail to transmit their characteristics uniformly to their offspring, even such "second generation" seed produced by relatively uniform seedling progenies would doubtless be preferable to seed from trees that have not been subjected to "progeny tests".

Critical evidence as to the relative merits of the best seedling progenies and of budded clones is lacking. Since the meritorious seedling progenies were not discovered until 1942 or later, test orchards in which the most promising clones are compared with outstanding seedling progenies have not yet come into bearing. In view of the fact that the use of budded stock would involve some additional investment, it seems wise to await more evidence before making definite recommendations. Whichever ultimately proves the better, the industry is already assured of trees that are much more uniformly productive and that bear fruit of considerably better oil content than the trees in present bearing orchards.

These results have been accomplished by means of a very simple but extensive program of selection and testing. From a long-term point of view, many new clones are being tested and controlled pollinations are being made in an attempt by crossing to combine desirable characters of different trees and by inbreeding to isolate genotypes that may later be worthy of recombination. However, such work will require many years to reach fruition.

From time to time during the last 8 years, what might be termed critical nutritional disturbances have occurred in tung orchards in one district or another. For example, in July and August of 1941 a serious disorder characterized by interveinal chlorosis and necrosis of the leaves with resultant premature defoliation and low oil content of fruit, occurred in many tung orchards in southern Georgia, northwestern Florida, and southern Alabama. Opinions as to the cause, ranging from excess water to deficiency of one or more nutrient elements, were expressed by experienced growers and professional personnel. Drosdoff and Painter (13) analyzed leaves from the affected trees and found them low in potassium and high in magnesium content, as compared with leaves from trees that did not exhibit the symptoms. The diagnosis was confirmed by field plot trials conducted in 1942. Fertilizer formulas for orchard use were adjusted accordingly and the trouble has now practically disappeared from orchards of well-informed tung growers. In a similar manner deficiencies of copper and of magnesium occurring in certain areas of north central Florida, were diagnosed and corrective measures worked out jointly by members of the staffs of the Bureau of Plant Industry, Soils, and Agricultural Engineering and of the Florida Experiment Station (11, 12).

Leaf analysis proved to be such an effective tool that since 1941 it has been used extensively in much of the experimental work, both in the field and in the greenhouse. It seems difficult to standardize soil

tests for use with tree crops but leaf analysis supplies the critical information on what the tree itself has been able to take from the soil. As Shear, Crane, and Myers (52) have suggested, it provides a useful means for correlating results at different locations in the field with the results of carefully controlled sand culture experiments. To date its greatest service has been in identifying elements that are in or near the deficiency range.

In tung investigations, as in most other similar spheres of agricultural experimentation, field plot trials play an important part. The field plot is the final proving ground for the clone and for all cultural practices. Carefully controlled laboratory experiments, biochemical investigations, and field observations may suggest improvements in horticultural practice, but it is well to test them experimentally in the field before recommending them. However, horticultural literature gives ample evidence that failure to take all sources of error into account, insufficient replication, and other similar mistakes may cause field plot trials to yield unreliable information. Much depends on the selection of an appropriate experimental design, which together with the corresponding statistical analysis will give an unbiased estimate of treatment differences and also a measure of the degree of reliability of the results.

Field plot experiments with tung present more than average difficulty. One is dealing with large perennial plants of seedling origin and the error due to individual differences between trees is much greater than in clonal orchards. Again the heavy rainfall of the tung-growing areas makes contour planting essential and thus it is especially difficult to arrange plots in latin square or even in randomized block designs. Contour planting also introduces another serious source of error, variable distances between rows. Finally the soils of the southeastern Coastal Plain are rather variable, and the tung tree is exceedingly sensitive to changes in soil texture or drainage. On the other hand, the tung industry offers one material advantage, extensive orchards from which to choose experimental plots.

Setting up a large number of experiments at the different laboratories afforded a good opportunity to try a number of different designs. Simple randomized block experiments have been used for many purposes, including tests involving 15 to 25 clones and seedling progenies, which at first were set up with single-tree plots in 10 replications. Such a design would be very efficient except that within a few years there are too many missing plots. Plots of four trees each are now used, with five replications; and when, after a few years, some individual trees are lost, some plots consist of three trees or rarely of only two. According to strict mathematical procedure, a method of analysis should be used that compensates for these unequal frequencies. However, such methods are laborious and we seem to find that little loss of information results from the use of the conventional analysis of variance, using as plot readings the means of the two, three, or four trees, as the case may be. Everything considered, this plan is proving more satisfactory than the use of single-tree plots in which so many plots are often found missing that the only analysis possible is

one in which total variation is broken down into (a) varieties and (b) error, completely ignoring replications. In more extensive variety trials a lattice design has been used; one experiment begun in 1944 includes a total of 64 sorts, mostly clones but some seedlings. There are replications of the same experiment near Kiln, Mississippi, Saucier, Mississippi and Thomasville, Georgia. A similar design was used in 1940 for comparing 169 seedling progenies in the nursery in Pearl River County, Mississippi, and it afforded rather precise readings on size and variability of the trees (30).

Split-plot designs have been found to be adapted to a wide variety of uses. For example, the method of pruning that is best for one clone may differ from that which is best for another. Hence, in some of the clonal trials a split-plot design has been used, each clonal plot being divided into subplots according to methods of pruning. In some experiments, particularly those involving culture with different types of implements, rather large plots are necessary. The efficiency, that is, information obtained per hour of the investigator's time, may be improved by subdividing cultural plots, for example, into subplots of different clones. Very precise data on performance of different clones have thus been obtained and at the same time evidence on specific interactions of the clone with different types of culture.

Ordinarily the major advantage of the split-plot design is that it permits ascertaining the effect of some factors in the experiment more precisely than others. This is accomplished on the simple basic principles that treatments located close together in the field may be compared more accurately than those that are located some distance apart and that precision increases with the number of replications. In split-plot experiments, each main plot provides a complete replication of the subplot treatments. Thus factors that require very fine distinctions are used for the subplots. For example, in an experiment with rootstocks for budded tung trees the main plots consist, respectively, of eight clones, and 20 subplots within each main plot are made up of trees worked on as many different rootstocks. A high degree of precision is attained for comparisons between rootstocks and the interaction of rootstock with clone, at the expense of precision in comparing different clones, which in this case is not the prime objective. To make it representative, the experiment is set up with two replications at each of three locations, Folsom, Louisiana, near Kiln, Mississippi, and near Lloyd, Florida.

Some results of great commercial significance to tung orchardists have been obtained in field plot experiments with fertilizers. In the beginning it was thought that symmetrical incomplete block designs (19, 55) would be advantageous for fertilizer experiments because good error control for the highly variable soils was to be expected. Possibly because of failure to select the most advantageous treatments, results were disappointing, as were also results from some simple randomized block experiments set up with five treatments, as many as eight trees per plot, and five replications. On the other hand rather extensive factorial experiments were found to provide exceptionally reliable results.

The first factorial experiment was set up at Pine Grove, Louisiana, in an orchard where variations in the internal drainage of the soil presented very serious difficulties. Nevertheless, it was soon evident that responses of the trees to fertilizer were being determined with an almost unbelievable degree of precision. In this experiment three levels of nitrogen, three of phosphorus, and three of potassium were used, the various combinations making a total of 27 treatments, each of which was used on plots comprising 12 trees in four basic replications. It appeared in 1940 that the oil content of the kernels from trees receiving the low, intermediate, and high applications of nitrogen was, respectively, 60.6, 59.3, and 59.0 per cent. Three relatively small differences were supported by an observed *F* value of 7.86 where a value of 7.76 is required for statistical significance at the .001 level. Some very well qualified authorities were loathe to believe that these results were valid; nevertheless, in spite of varying seasonal factors that had a profound influence on oil content of the kernel, they were obtained consistently in the same experiment in succeeding years, and have been confirmed again and again in similar experiments in several of the tung-producing States. The high degree of precision attained is undoubtedly due to what the statisticians term "internal replication". In the experiment at Pine Grove there were 108 plots, one-third of which received the low level of nitrogen, one-third the intermediate level, and one-third the high level. Since in this experiment statistical analysis of oil content showed no interaction of the effect of nitrogen with level of phosphorus or with level of potassium, there were in effect 36 replications of each level of nitrogen. The average oil content for each level of nitrogen was thus determined from 36 samples, one from each plot, representing a total of more than 400 trees. The large number of plots and of trees had leveled out errors due to soil variation and characteristics of individual seedling trees. The effect of nitrogen was determined with the same degree of precision as if the experiment had been devoted to nitrogen alone. Yet through the factorial design, the effects of phosphorus and potassium were determined simultaneously and with the same degree of precision. In a sense, three experiments were had at the price of one.

It would be misleading to leave the impression that all responses of the trees were determined with the same high degree of precision as the oil content. Many research workers fail to realize that in every experiment some responses are determined with more precision than others. Oil content of the kernel of individual tung trees is relatively constant in comparison, for instance, with pounds of air-dry fruit produced per tree. Accordingly effects of fertilizer treatment on yield are determined with less precision than effects on oil content of kernel. However, the efficiency of the factorial experiment as compared with other designs is the same in the two cases. The large number of plots and of individual trees tends to level out errors in yield, oil content, or any other response. The principle also applies to small-scale experiments. Increased precision and greater output of information per hour of the investigator's time has been had through factorial design of experiments involving only 24 trees. As is indicated by Yates (54),



an experiment of the type at Pine Grove is useful principally for determining basic principles in the response of plants to treatment. As was indicated earlier, when basic principles have been fairly well worked out, it is advantageous to set up less extensive experiments, perhaps with only one replication at each of a considerable number of locations, representative of the area to which conclusions are expected to be extended.

Experiments of the type described for Pine Grove were soon set up in more favorable locations and have afforded results of the most profound significance to the tung industry. Thus Sitton and Loustalot (53) were able to show that at Bush, Louisiana, nitrogen equivalent to 3 pounds of ammonium nitrate applied to 5-year-old trees in 1943 improved yield of oil in 1944 by 45 per cent. Furthermore they are able to determine with assurance just how the yield was raised. Since in tung all the blossoms are produced terminally on the shoots, yield is conditioned by the number of terminal buds. Nitrogen improved the vegetative growth of the trees and increased the number of new terminal shoots by approximately 10 per cent. The nitrogen increased the number of pistillate flowers to an even more marked extent, the average number of flowers initiated in each terminal bud being 1.64 at the low level of nitrogen and 2.19 at the high level, an increase of 33.3 per cent. It was indicated previously that kernels of fruit borne on trees at a high plane of nitrogen nutrition have a slightly lower percentage of oil than the kernels of fruit from trees with a low nitrogen supply; but Sitton and Loustalot (53) were able to demonstrate that the relative weight of the kernel in the whole fruit was increased by an amount that more than offset the loss in percentage of oil, and oil in the whole fruit was increased from 20.7 to 21.7 per cent. The resultant of these various factors was a yield of 7.64 pounds of oil per fertilized tree, as opposed to 5.24 pounds per tree where no nitrogen was used.

Experiments at various other locations soon demonstrated that the principles established by the nitrogen fertilizer experiment at Bush may be extended to most of the tung growing areas, although in sandy soils of the peninsula of Florida some other factors, as yet undetermined, seem to limit the response of tung trees to nitrogen. Wartime fertilizer formulas were such that tung growers were spending the major share of their fertilizer dollar for relatively unimportant elements. The information from these experiments was seized upon; it was found that ammonium nitrate could be procured and today several thousands of tons of this nitrogen carrier are applied annually to orchards throughout most of the tung-growing areas, from north-west Florida to Texas. In one instance this change in fertilizer practice increased the 1946 gross income of one single large-scale grower by at least \$100,000.

Another factorial experiment at Monticello, Florida, conducted jointly by our Cairo, Georgia, and Gainesville, Florida laboratories, is now beginning to yield reliable results under difficulties that might seem unsurmountable. To follow up results obtained in controlled sand culture experiments, it was desired to set up an experiment in

which widely different ratios of nitrogen, phosphorus, potassium, calcium, and magnesium, would be induced in tung trees in the orchard. Each of the five elements was applied at two levels based on the composition of the leaves as determined by previous analysis, and the resulting combinations constituted 32 separate treatments, each to be applied to plots of six trees in three basic replications. It was necessary to use an orchard that had not previously been heavily fertilized, and in the one most suitable the trees and the soil were so variable that it was virtually impossible to set up the 32 plots of any one replication under even reasonably uniform conditions. A technique was adopted in which each replication was divided into four blocks of eight plots each. The object was to have all plots within each block on reasonably uniform soil, but the soil of the different blocks was not necessarily similar. It was feasible to set up the experiment on that basis.

Subdividing a replication into different blocks is confusing to some biologists, because the treatment combinations in one block are not identical with those in another. Actually, if properly set up, all blocks receive the same basic treatments; the difference is in the way they are combined. The plan is such that in making comparisons of the treatments and their most important interactions, differences between blocks cancel out. The experimental errors are reduced because they depend only on variation within blocks. To get this increased precision certain unimportant information had to be sacrificed. In the Monticello experiment the effects of two three-factor interactions and one four-factor interaction were "confounded", as the statisticians say, with block effects and could not be evaluated. The word "confounded" tends to connote something unpleasant, and to a horticultural audience the word "pooled" is more informative. The effect of the interactions listed was "pooled" with that of soil and other differences between blocks, just as the fruit of different growers is pooled in a cooperative packing plant, and hence can never again be separated.

Since the experiment at Monticello was considered very important, the composition of the leaves from every plot was determined in August 1944, prior to beginning the differential treatments. To illustrate the data, the percentages of potassium in the dry weight of leaves for the 12 blocks are given in Table I. They show the trees to be variable

TABLE I—PERCENTAGE OF POTASSIUM IN TUNG LEAVES (DRY BASIS) PRIOR TO TREATMENT (FACTORIAL EXPERIMENT, MONTICELLO, FLORIDA, AUGUST 1944)

Block	Replication		
	I	II	III
a.....	0.49	0.70	0.41
b.....	0.84	0.70	0.53
c.....	0.55	0.74	0.52
d.....	0.60	0.52	0.49

in potassium content, but all in or near the deficiency range. The average yields of air-dry fruit per tree for the season of 1944 were also determined and are given in Table II. Data on composition and yield

TABLE II—AVERAGE YIELD AIR-DRY TUNG FRUIT, IN POUNDS PER TREE PRIOR TO TREATMENT (FACTORIAL EXPERIMENT, MONTICELLO, FLORIDA, 1944)

Block	Replication		
	I	II	III
a.....	31.3	36.4	19.6
b.....	33.5	36.3	18.7
c.....	25.0	30.8	26.5
d.....	22.9	35.0	11.7

were obtained for each one of the 96 plots, and without going into detail it may be said that our staff members had made such an excellent job of setting up the plots that variations between plots within each block were usually not serious.<sup>2</sup> The fertilizers applied in the spring of 1945 had little or no bearing on the yields of that season, which were already limited by the number of pistillate flower buds initiated in 1944, before differential treatments were used; but they could affect composition of the crop. When the chemical analyses had been made and the statistical computations performed, it was found that the 0.89 pound of nitrogen per tree had *decreased* oil in the kernel by 2.48 percentage units and that 1.82 pounds of K<sub>2</sub>O per tree had *increased* the oil content by 1.66 percentage units, results that check perfectly with others secured elsewhere under less difficult conditions.

Fertilizers applied in 1945 are reflected in the yields of 1946, a crop that has not yet been harvested at this writing. However, seed stems on tung trees persist for several seasons and hence it is a simple matter to count 1946 fruits versus 1945 seed stems on representative branches and estimate the ratio of yield in 1946 to yield in 1945. An analysis of such data showed that both nitrogen and potassium had increased yields, but that the effect of the nitrogen was the more important; and also that there was a highly significant first order interaction between nitrogen and potassium. This means that the effect of potassium was different at the low level of nitrogen from its effect at the high level of nitrogen; hence it is appropriate to break the experiment down into four groups of plots (Table III): (a)

TABLE III—EFFECT OF NITROGEN AND POTASSIUM ON RATIO OF 1946 TO 1945\* YIELDS (FACTORIAL EXPERIMENT, MONTICELLO, FLORIDA)

Fertilizer Applied Per Tree (Pounds)		Ratio 1946/1945 Crop
Ammonium Nitrate	Muriate of Potash	
0.28	0.36	2.30
0.28	4.00	2.49
3.12	0.36	3.15
3.12	4.00	4.17

Least significant difference at 0.05, 0.59; at 0.01, 0.79; at 0.001, 1.05

\*Crop of 1945 reflects the uniform fertilization of 1944 rather than the differential treatments of the spring of 1945, since the pistillate flower buds had been formed in the summer of 1944.

<sup>2</sup>Where unavoidable differences occur, the statistical method of covariance can usually be used to refine the analysis.

those that received the low level of both nitrogen and potassium, for which the ratio of yield in 1946 to yield in 1945 was found to be 2.30; (b) those that received the high level of potash but the low level of nitrogen, for which the ratio is 2.49; (c) those that received the high level of nitrogen but low level of potassium, for which the ratio is 3.15; and (d) those that received the high level of both nitrogen and potassium, for which the ratio is 4.17. This brings out the whole picture; namely, that nitrogen has increased yields of all trees but that potassium effected a substantial increase in yield only on trees that received the high level of nitrogen. In spite of all difficulties the experiment had produced clear-cut reliable results.

The immediate response to potassium at Monticello was to be anticipated from the leaf analyses, but even in soils that have considerable available potassium, for example at Bush, Louisiana, heavy crop production induced by a high level of nitrogen nutrition soon tends to create a potassium deficiency in tung. Without going into the evidence, it may be stated that while fertilization with nitrogen temporarily increases yields of tung, the long-term fertilizer program must include potassium and phosphorus, preferably applied to cover crops at seedling time.

And so, in the words of Marshall Ballard, Jr., Secretary of the American Tung Oil Association, "Tung Marches On". The domestic tung oil industry was a godsend to America when at the outbreak of war stocks of this highly essential war material were at low ebb and the Chinese supply was completely cut off. A ceiling price was set that would encourage domestic production, and at the instigation of the War Production Board special programs were administered through the Agricultural Adjustment Administration to assist owners of orchards to produce and turn under cover crops. Under these circumstances the industry has thrived and owners of bearing orchards have received satisfactory returns. It is probable that the industry would have "marched on" even without the research of the last eight years. However, there is no doubt that this research has already increased production substantially, and it will be of still greater value when the industry again meets world-wide competition. The good yields to be anticipated from planting improved varieties on suitable soil and through proper fertilization and culture, together with economies resulting from improved equipment now being developed by the Division of Agricultural Engineering (39) enable the tung grower to face the future with optimism.

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## MEMBERSHIP ROLL

ABBOTT, C. E. ....	University of Florida, Gainesville, Fla.
ABMEYER, ERWIN .....	Northeast Kansas Exp. Fields, Wathena, Kans.
ACKER, ROY M. ....	5615 S. Campbell, Chicago, Ill.
ADAMSON, ROBERT M. ....	Dominion Experiment Sta., Saanichton, B. C.
ADRIANCE, G. W. ....	A. & M. College of Texas, College Station, Texas.
AGGEN, A. F. ....	Box 260, Camarillo, Calif.
AGNEW, ELBERT L. ....	58 Charles Ave., Youngstown, Ohio.
ALBAN, E. K. ....	Ohio Experiment Station, Columbus, Ohio.
ALBEN, A. O. ....	606 Court House, Shreveport, La.
ALDERMAN, DeFOREST C. ....	Louisiana State University, Baton Rouge, La.
ALDERMAN, W. H. ....	University of Minnesota, St. Paul, Minn.
ALDRICH, W. W. ....	Professional Arts Bldg., Hagerstown, Md.
ALLEN, ALBERT G. ....	Salisbury, Md.
ALLEN, F. W. ....	University of California, Davis, Calif.
ALLEN, HARVEY T. ....	Lacombe, Alberta, Canada.
ALLMENDINGER, D. F. ....	Washington Experiment Sta., Vancouver, Wash.
ALLWRIGHT, WINSTON J. G. P. O. ....	Box 1158, Pretoria, S. A.
ALVAREZ, VICTORINO .....	Jardin El Clavel, Marianao, Habana, Cuba.
AMERINE, MAYNARD A. ....	University of California, Davis, Calif.
AMSTEIN, W. G. ....	Kansas State College, Manhattan, Kans.
ANDERSEN, E. MILTON .....	Utah State Agr. College, Logan, Utah.
ANDERSON, EMIL .....	University of Manitoba, Winnipeg, Manitoba.
ANDERSON, F. W. ....	826 Twenty-second St., Merced, Calif.
ANDERSON, M. S. ....	Plant Industry Station, Beltsville, Md.
ANDERSON, ROBERT C. ....	University of Tennessee, Knoxville, Tenn.
ANDERSON, W. S. ....	Mississippi State College, State College, Miss.
ANDRUS, C. F. ....	Vegetable Breeding Lab., Charleston, S. C.
ANSTAY, THOMAS H. ....	University Farm, St. Paul, Minn.
ANTHONY, R. D. ....	Pennsylvania State College, State College, Pa.
APP, FRANK. ....	Bridgeton, N. J.
APPLE, S. B., JR. ....	Texas Extension Service, Weslaco, Texas.
ARKELL, W. C. ....	10 East 40th St., New York City.
ARMSTRONG, JOHN A. ....	408 N. Euclid Ave., Ontario, Calif.
ARNOLD, CHARLES Y. ....	Cook County Experiment Sta., Des Plaines, Ill.
AROIAN, H. BRUCE. ....	Box 818, Blacksburg, Va.
ASEN, SAM. ....	410 Ascot Rd., Oreland, Pa.
ASHTON, CLARENCE D. ....	P. O. Box 137, Provo, Utah.
AUTCHER, E. C. ....	Pineapple Research Institute, Honolulu, T. H.
AUSTIN, LLOYD. ....	Rainbow Hybridizing Gardens, Placerville, Calif.
BABB, M. F. ....	Cheyenne Hort. Field Sta., Cheyenne, Wyo.
BAILEY, J. S. ....	Massachusetts State College, Amherst, Mass.
BAILEY, R. M. ....	University of Maine, Orono, Me.
BAILEY, W. K. ....	Georgia Experiment Station, Experiment, Ga.
BAKER, CLARENCE E. ....	Purdue University, Lafayette, Ind.
BALDWIN, HERBERT E., JR. ....	Bayberry Orchards, Westport, Conn.
BALLARD, W. S. ....	U. S. Dept. Agr., Fresno, Calif.
BALOG, PEDRO P. ....	University Hotel, Davis, Calif.
BANGA, O. ....	25 Heerenstraat, Wageningen, Holland.
BANTA, ELDON S. ....	Lebanon, Ohio.
BARNES, W. C. ....	South Carolina Truck Exp. Sta., Charleston, S. C.
BARNETT, R. J. ....	Kansas State College, Manhattan, Kans.
BARR, C. GUINN. ....	South Cedar St., Lansing, Mich.
BARRONS, KEITH C. ....	133 Durand St., East Lansing, Michigan.
BARSS, A. F. ....	University of British Columbia, Vancouver, B. C.
BASS, I. H. ....	Lumberton, Miss.
BATCHLOR, L. D. ....	Citrus Experiment Station, Riverside, Calif.
BATCHELLER, O. A. ....	California Polytechnic School, San Dimas, Calif.
BATJER, L. F. ....	Box 99, Wenatchee, Washington.

BATSON, F. S.	Mississippi State College, State College, Miss.
BAUDONNET, P. E.	302 E. Street, Davis, Calif.
BEACH, G. A.	Colorado State College, Ft. Collins, Colo.
BEAMS, GEOFFREY H.	Box 528, Falmouth, Mass.
BEATTIE, J. H.	Plant Industry Station, Beltsville, Md.
BEATTY, ROBERT H.	American Chem. Paint Co., Ambler, Pa.
BEAUMONT, J. H.	Hawaii Experiment Sta., Honolulu, T. H.
BECKENBACH, J. R.	Vegetable Crops Lab., Bradenton, Fla.
BECNEL, I. J.	Freeport Sulphur Co., New Orleans, La.
BEGLAU, ROLLAND A.	430 N. 15th St., Corvallis, Oregon.
BELL, HUGH P.	Dalhousie University, Halifax, Nova Scotia.
BELL, ROBERT S.	Rhode Island State College, Kingston, R. I.
BEMIS, WILLIAM P.	University of California, Davis, Calif.
BENDER, EDWARD K.	University of Maryland, College Park, Md.
BENNETT, J. P.	University of California, Berkeley, Calif.
BERESFORD, B. C.	University of Minnesota, Crookston, Minn.
BERRY, J. B.	332 Ave. E, S. E., Winter Haven, Fla.
BEVAN, M. R.	Canada Packers Ltd., Boniface, Manitoba.
BHANDALL, BIR S.	P. S. Muhar Publications Div., Delhi, India.
BHOY, SURENDRA.	1027 Ocean Ave., Santa Monica, Calif.
BIALE, J. B.	University of California, Los Angeles, Calif.
BIEBEL, JOSEPH P.	312 N. 4th Rd., S. Miami, Fla.
BIEBERDORF, G. A.	Oklahoma A. & M. College, Stillwater, Okla.
BINKLEY, A. M.	Colorado State College, Ft. Collins, Colo.
BIRKELAND, C. J.	818 West Vine St., Champaign, Ill.
BLACKBURN, H. W.	Eikenhof, Elgin, South Africa.
BLACKHURST, H. T.	A. & M. College of Texas, College Station, Texas.
BLACKMON, G. H.	University of Florida, Gainesville, Fla.
BLAHA, JOS.	Brno 3, Zemedelska, Czechoslovakia.
BLAIR, J. C.	P. O. Box 57, Urbana, Ill.
BLAKE, M. A.	New Jersey Experiment Sta., New Brunswick, N. J.
BLANCHARD, JAY L.	209 Adams St., Ithaca, N. Y.
BLASBERG, C. H.	University of Vermont, Burlington, Vt.
BLIGH, R. D. L.	Experiment Station, Kentville, Nova Scotia.
BLODGETT, C. O.	529 Hathway Ave., San Luis Obispo, Calif.
BLOW, M. H.	Joseph E. Seagrams Corp., Louisville, Ky.
BOLLER, C. A., JR.	Oregon State College, Corvallis, Ore.
BOOYE, B. T.	Box 125, Sunnyvale, Calif.
BOSWELL, V. R.	Plant Industry Station, Beltsville, Md.
BOUQUET, A. G. B.	Oregon State College, Corvallis, Ore.
BOWERS, J. L.	Mississippi State College, State College, Miss.
BOWLES, EDWARD J.	2360 Chestnut St., San Francisco, Calif.
BOYD, JOSEPH H.	Pennsylvania State College, State College, Pa.
BOYD, LOYD Q.	6253 Van Buren Ave., Hammond, Ind.
BOYD, WILLIAM I.	Box 15, Wyoming, Del.
BOYNTON, DAMON.	Cornell University, Ithaca, N. Y.
BRAATHEN, E. H.	Bot. 613, Prince George, B. C.
BRADFORD, F. C.	U. S. Plant Introduction Garden, Glenn Dale, Md.
BRADLEY, RUSSELL H.	Purdue University, West Lafayette, Ind.
BRASE, KARL D.	New York State Experiment Station, Geneva, N. Y.
BRASHER, E. P.	University of Delaware, Newark, Del.
BRATLEY, C. O.	5202 Roosevelt St., Bethesda, Md.
BREAK, RICHARD.	Room 20, Federal Bldg., Fresno, Calif.
BREGGER, J. T.	Soil Conservation Service, Clemson, S. C.
BRIERLEY, PHILIP.	Plant Industry Station, Beltsville, Md.
BRIERLEY, W. G.	University of Minnesota, St. Paul, Minn.
BRIGHTWELL, W. T.	Georgia Experiment Station, Tifton, Ga.
BRISON, F. R.	A. & M. College of Texas, College Station, Tex.
BRITTINGHAM, WM. H.	Texas Experiment Station, College Station, Tex.
BROOKS, R. M.	University of California, Davis, Calif.
BROWN, BAILEY E.	1207 Delafield Pl. N. W., Washington, D. C.
BROWN, DILLON S.	Hawaiian Pineapple Co., Ltd., Honolulu, Hawaii.
BROWN, G. B.	Cheyenne Hort. Station, Cheyenne, Wyo.
BROWN, G. G.	Oregon Experiment Sta., Hood River, Ore.



- BROWN, H. D. . . . . Ohio State University, Columbus, Ohio.  
 BROWN, J. G. . . . . University of California, Davis, Calif.  
 BROWN, K. E. . . . . Lyons, N. Y.  
 BROWN, PAUL D. . . . . Box 45, Algonia, Wash.  
 BROWN, RALPH T. . . . . U. S. Dept. Agr., Cairo, Ga.  
 BRYAN, O. C. . . . . Florida Southern College, Lakeland, Fla.  
 BRYANT, L. R. . . . . Washington State College, Pullman, Wash.  
 BULLARD, IRVIN T. . . . . Purdue University, Lafayette, Ind.  
 BULLOCK, RICHARD M. . . . . Agricultural Experiment Station, Wenatchee, Wash.  
 BURKHOLDER, C. L. . . . . Purdue University, Lafayette, Ind.  
 BURRELL, A. B. . . . . Cornell University, Ithaca, N. Y.  
 BUSHEY, D. J. . . . . Cornell University, Ithaca, N. Y.  
 BUSHNELL, JOHN. . . . . Ohio Experiment Station, Wooster, Ohio.  
 BUTTERFIELD, N. W. . . . . Rhode Island State College, Kingston, R. I.  
 BYERS, EARL. . . . . Vincennes, Ind.
- CAIN, JOHN C. . . . . Cornell University, Ithaca, N. Y.  
 CAIN, ROBERT F. . . . . A. & M. College of Texas, College Station, Texas.  
 CALDIS, P. D. . . . . 101 California St., San Francisco, Calif.  
 CALDWELL, J. S. . . . . Plant Industry Station, Beltsville, Md.  
 CAMERON, S. H. . . . . University of California, Los Angeles, Calif.  
 CAMP, A. F. . . . . Citrus Experiment Station, Lake Alfred, Fla.  
 CAMP, W. B. JR. . . . . R. D. 1, Bakersfield, Calif.  
 CAMPBELL, JOHN A. . . . . Crystal Springs Exp. Sta., Crystal Springs, Miss.  
 CAMPBELL, R. W. . . . . Kansas State College, Manhattan, Kansas.  
 CARDIFF, IRA D. . . . . Cardiff & Co., Yakima, Wash.  
 CAREW, JOHN. . . . . Cornell University, Ithaca, N. Y.  
 CARLETON, R. MILTON. . . . . 10 W. Randolph St., Chicago, Ill.  
 CARLSON, ROBERT F. . . . . Upper Peninsula Exp. Sta., Chatham, Mich.  
 CARMON, Y. . . . . Box 15, Rehovot, Palestine.  
 CAROLUS, R. L. . . . . Michigan State College, East Lansing, Mich.  
 CARR, ELLWOOD J. . . . . Box 195, Walnut Grove, Calif.  
 CARSTENS, MARTIN S. . . . . Western Washington Exp. Sta., Puyallup, Wash.  
 CARTER, ROGER W. . . . . 1901 1/4 Orchard Ave., Los Angeles, Calif.  
 CASSERES, ERNEST H. . . . . Inter-Amer. Inst. of Agr. Sci. Turrialba, Costa Rica.  
 CHADWICK, L. C. . . . . Ohio State University, Columbus, Ohio.  
 CHANDLER, F. B. . . . . East Wareham, Mass.  
 CHANDLER, W. H. . . . . University of California, Los Angeles, Calif.  
 CHANG, WEN-TSAI. . . . . University of Nanking, Nanking, China.  
 CHAPLIN, CARL E. . . . . University Farm, Olney, Ill.  
 CHAPPELL, WILLIAM E. . . . . University of Connecticut, Storrs, Conn.  
 CHARLES, F. M. . . . . 145 S. American St., Stockton, Calif.  
 CHASE, SPENCER B. . . . . Forests Products Sec. T.V.A., Norris, Tenn.  
 CHEVALIER, MARCEL. . . . . Versailles-Seine et Oise, France.  
 CHEONKAR, V.P.S. . . . . 102 W. 6th Ave., Columbus, Ohio.  
 CHILDERS, N. F. . . . . U. S. Dept. Agr., Mayaguez, P. R.  
 CHILDS, W. H. . . . . West Virginia University, Morgantown, W. Va.  
 CHRIST, ERNEST G. . . . . New Jersey Experiment Station, New Brunswick, N. J.  
 CHRISTOPHER, E. P. . . . . Rhode Island State College, Kingston, R. I.  
 CHROBOCZEK, E. . . . . Osada Palacowa, Skierniewice, Poland.  
 CLAPP, RAYMOND K. . . . . 7 Willowbrook Road, Storrs, Conn.  
 CLARK, B. E. . . . . 805 Birch Rd., East Lansing, Mich.  
 CLARK, JOHN C. . . . . County Agent, Jackson, Tenn.  
 CLARK, J. H. . . . . Cranguyma Farm, Long Beach, Wash.  
 CLARKE, A. E. . . . . Plant Industry Station, Beltsville, Md.  
 CLARKE, J. R. . . . . Milton, N. Y.  
 CLARKE, W. S., JR. . . . . Pennsylvania State College, State College, Pa.  
 CLAYPOOL, L. L. . . . . University of California, Davis, Calif.  
 CLEGG, HAROLD H. . . . . 1213 Wea Ave., Lafayette, Ind.  
 CLORE, W. J. . . . . Box 425, Prosser, Wash.  
 CLOSE, A. W. . . . . U. S. Plant Introduction Garden, Glenn Dale, Md.  
 COCHRAN, GEORGE W. . . . . The Rockefeller Institute, Princeton, N. J.  
 COCHRAN, H. L. . . . . Pomona Products Co., Griffin, Ga.

- COCHRAN, L. C. .... Citrus Experiment Station, Riverside, Calif.  
 COCKRUM, E. E. .... Gallatin Valley Seed Co., Bozeman, Mont.  
 CODY, L. R. .... Vickery Ave., Saratoga, Calif.  
 COIT, J. E. .... Fallbrook, Calif.  
 COLLINS, C. M. .... Dept. of Agriculture, Truro, Novo Scotia.  
 COLLINS, WM. H. .... Sec. Iowa State Hort. Soc., Des Moines, Iowa.  
 COMIN, DONALD. .... Ohio Experiment Station, Wooster, Ohio.  
 CONDIT, I. J. .... Citrus Experiment Station, Riverside, Calif.  
 CONNORS, C. H. .... New Jersey Experiment Sta., New Brunswick, N. J.  
 COOLEY, J. S. .... Plant Industry Station, Beltsville, Md.  
 COOMBS, ROGER C. .... Henniker, N. H.  
 COOPER, J. R. .... University of Arkansas, Fayetteville, Ark.  
 COOPER, WILLIAM C. .... Texas Sub-Station No. 15, Weslaco, Texas.  
 CORDNER, H. B. .... Oklahoma A. & M. College, Stillwater, Okla.  
 CORMAN, H. E. .... 2200 St. Clair Ave., W., Toronto, Ont.  
 COTTON, Robert H. .... 100 Brookline Ave., Boston, Mass.  
 COULTER, LEWELLYN L. .... Michigan State College, East Lansing, Mich.  
 COURT, W. E. .... Box 347, Loomis, Calif.  
 COUSIN, PIERRE. .... 10 Avenue Dar-El-Maghzen, Rabat, Maroc.  
 COVER, CHARLES J. .... Charter Seed Co., Twin Falls, Idaho.  
 COWART, F. F. .... Georgia Experiment Sta., Experiment, Ga.  
 COWDEN, LLOYD C. .... Parma Branch Sta., Parma, Idaho.  
 COWGILL, W. H. .... American Embassy, Guatemala City, C. A.  
 CRAM, W. H. .... Experimental Farms Service, Indian Head, Sask.  
 CRANE, H. L. .... Plant Industry Station, Beltsville, Md.  
 CRANE, JULIAN C. .... University of California, Davis, Calif.  
 CRAWFORD, CALVIN C. .... Philippine Packing Corp., Cagavan Misamis  
     Oriental, P. I.  
 CRAWFORD, CARL L. .... General Delivery, Prosser, Wash.  
 CROCE, FRANCISCO M. .... Mendoza, Argentina.  
 CROCKER, WILLIAM. .... Boyce-Thompson Institute, Yonkers, N. Y.  
 CROSS, F. B. .... Oklahoma A. & M. College, Stillwater, Okla.  
 CROWLEY, D. J. .... Cranberry-Blueberry Exp. Sta., Long Beach, Wash.  
 CRUMMETT, DUANE O. .... New Jersey Experiment Station, New Brunswick,  
     N. J.  
 CULBERT, JOHN R. .... University of Illinois, Urbana, Ill.  
 CULLINAN, F. P. .... Plant Industry Station, Beltsville, Md.  
 CUMMING, PATRICK. .... University College, Dundee, Scotland.  
 CUNNINGHAM, DEREK H. .... 70 College Park, Davis, Calif.  
 CURRENCE, T. M. .... University of Minnesota, St. Paul, Minn.  
 CURTIS, L. C. .... Connecticut Experiment Sta., New Haven, Conn.  
 CURTIS, O. F. .... Cornell University, Ithaca, N. Y.  
 CURTIS, O. F., JR. .... New York State Experiment Station, Geneva, N. Y.  
 CURTIS, RALPH W. .... Cornell University, Ithaca, N. Y.  
  
 DANIELSON, L. L. .... Virginia Truck Experiment Sta., Norfolk, Va.  
 DANKS, F. M. .... Canterbury, Victoria, Australia.  
 DARROW, G. M. .... Plant Industry Station, Beltsville, Md.  
 DAVENPORT, S. LATHROP. .... Worcester, Mass.  
 DAVIDSON, JOHN H. .... 54 Elkenburg St., South Haven, Mich.  
 DAVIDSON, O. W. .... New Jersey Experiment Sta., New Brunswick, N. J.  
 DAVIS, GLEN N. .... University of California, Davis, Calif.  
 DAVIS, HELEN I. .... 11 Windsor Ave., Buffalo, N. Y.  
 DAVIS, JOHN F. .... Michigan State College, East Lansing, Mich.  
 DAVIS, L. D. .... University of California, Davis, Calif.  
 DAY, L. H. .... University of California, Davis, Calif.  
 DE ALMEIDA, CARLOS R. M. .... Lisboa, Portugal.  
 DEAN, LESLIE L. .... Purdue University, Lafayette, Ind.  
 DEARBORN, C. H. .... New York State Experiment Station, Geneva, N. Y.  
 DEARBORN, R. B. .... Eastern States Farmers Exchange, Springfield, Mass.  
 DE CHAUNAC, A. .... T. G. Bright & Co., Ltd., Niagara Falls, Ontario.  
 DECOUR, SAMUEL C. .... Merchantville, N. J.  
 DEGMAN, E. S. .... U. S. Dept. Agr., Box 426, Medford, Ore.  
 DELWICHE, EDMUND D. .... 1140 Clark Way, San Jose, Calif.

- DE MAISONNEUVE GERARD. School of Agriculture, Ste-Martine, Quebec.  
DENISEN, ERVIN L. . . . . Iowa State College, Ames, Iowa.  
DEONIER, MARSHALL T. . . . . U. S. Hort. Station, Meridian, Miss.  
DERMEN, HAIG. . . . . Plant Industry Station, Beltsville, Md.  
DETJEN, L. R. . . . . University of Delaware, Newark, Del.  
DETWILER, S. B. . . . . 1028 N. Daniel St., Arlington, Va.  
DE WERTH, A. F. . . . . A. & M. College of Texas, College Station, Texas.  
DEWEY, DONALD H. . . . . U. S. Hort. Field Sta., Fresno, Calif.  
DICKEY, R. D. . . . . Florida Experiment Sta., Gainesville, Fla.  
DICKINSON, B. C. . . . . Sherwin-Williams Co., Bound Brook, N. J.  
DICKINSON, C. E. . . . . 500 Lafayette St., Jefferson City, Mo.  
DICKSON, B. T. . . . . Box 109, Canberra, F. C. T., Australia.  
DICKSON, W. C., JR. . . . . 99 George St., Hanover, Pa.  
DIXON, JAMES L. . . . . Calif. Packing Corp., Toppenish, Washington.  
DODGE, FREDERICK N. . . . . Lee Road, Covington, La.  
DOLAN, DESMOND. . . . . Rhode Island State College, Kingston, R. I.  
DONEEN, L. D. . . . . University of California, Davis, Calif.  
DORAN, W. L. . . . . Massachusetts State College, Amherst, Mass.  
DORSEY, M. J. . . . . University of Illinois, Urbana, Ill.  
DOUD, L. J. . . . . R. R. 1, Wabash, Ind.  
DOWD, O. J. . . . . Box 71, Paw Paw, Mich.  
DRAIN, B. D. . . . . Tennessee Experiment Sta., Knoxville, Tenn.  
DREWES, HARM. . . . . Oakview Seed Breeding Station, Rochester, Mich.  
DROSDOFF, MATTHEW. . . . . University Station, Gainesville, Fla.  
DRUEHL, W. C. . . . . Calif. Packing Corp., Portland, Oregon.  
DUNBAR, Charles O. . . . . University of Maryland, Fruit Lab., Hancock, Md.  
DUTTON, W. C. . . . . 523 Bailey St., East Lansing, Mich.  
DYE, H. W. . . . . Middleport, N. Y.
- EASTWOOD, THOMAS M. . . . . 210 Front St., Delphi, Indiana.  
ECKERSON, SOPHIA H. . . . . Francestown, New Hampshire.  
EDGEcombe, S. W. . . . . 63 Faires Park, Decatur, Ill.  
EDGERTON, L. J. . . . . Cornell University Station, Ithaca, N. Y.  
EDMOND, J. B. . . . . University Station, Baton Rouge, La.  
EDWARDS, C. J. . . . . 149 Notre Dame, East Winnipeg, Canada.  
EGGERT, RUSSELL. . . . . 145 Campus Ave., Ames, Iowa.  
EINSET, JOHN. . . . . New York State Experiment Station, Geneva, N. Y.  
ELLE, GEORGE O. . . . . Texas Technology College, Lubbock, Texas.  
ELLENWOOD, C. W. . . . . Ohio Experiment Station, Wooster, Ohio.  
ELLIS, N. K. . . . . Purdue University, Lafayette, Ind.  
ELLISON, J. HOWARD. . . . . Cornell University, Ithaca, N. Y.  
ELWELL, ROBERT N. . . . . Arrowhead Farm, R. D. 50, Vineyard Haven, Mass.  
EMMERT, E. M. . . . . University of Kentucky, Lexington, Ky.  
EMSWELLER, S. L. . . . . Plant Industry Station, Beltsville, Md.  
ENGLE, R. H. . . . . 616 Investment Bldg., Washington, D. C.  
ENZIE, J. V. . . . . New Mexico State College, State College, N. M.  
ENZIE, W. D. . . . . Snider Packing Co., Albion, N. Y.  
ERWIN, A. T. . . . . Iowa State College, Ames, Iowa.  
ESTY, J. R. . . . . National Cannery Ass'n., San Francisco, Calif.  
ETO, WILLIAM H. . . . . Corneli Seed Co., St. Louis, Mo.  
EVANS, STERLING. . . . . 305 Delaware, Kansas City, Mo.  
EWING, MRS. G. C. . . . . 1205 Muirlands Drive, La Jolla, Calif.  
EYRE, DAVID R. . . . . 1185 Main St., Santa Clara, Calif.  
EZELL, B. D. . . . . Plant Industry Station, Beltsville, Md.
- FAIRCHILD, S. J. . . . . Box 645, Santa Maria, Calif.  
FALKENBERG, GEORGE V. . . . . Purdue University, Lafayette, Ind.  
FARBER, RENA. . . . . Agricultural School for Girls, Nahalal, Palestine.  
FARISH, L. R. . . . . Delta Branch Experiment Station, Stoneville, Miss.  
FARNHAM, R. B. . . . . New Jersey Experiment Sta., New Brunswick, N. J.  
FAROOQUI, M. MOHIBULLA. . . . . 3415 Growhiguda, Hyderabad, (Deccan) India.  
FASLAGIC, MEHMEDALIJA. . . . . Sarajevo, Bosnia & Herzegovina, Yugoslavia.  
FAUST, F. B. . . . . Associated Seed Growers, Atlanta, Ga.  
FELBER, IRMA M. . . . . Michigan State College, East Lansing, Mich.

- FERREE, ROY J. . . . . Clemson College, S. C.  
 FILINGER, G. A. . . . . Kansas State College, Manhattan, Kans.  
 FINCH, A. H. . . . . U. S. Dept. Agr., Yuma, Arizona.  
 FINCH, JACK R. . . . . Bailey, N. C.  
 FINEMAN, ZOLA M. . . . . Agricultural Experiment Station, Palmer, Alaska.  
 FISCHER, CHARLES W., JR. . . . . Cornell University, Ithaca, N. Y.  
 FISHER, BARRETT . . . . . Westville Laboratories, Monroe, Conn.  
 FISHER, D. F. . . . . U. S. Dept. Agr., Washington, D. C.  
 FISHER, D. V. . . . . Dominion Experiment Station, Summerland, B. C.  
 FISHER, ELWOOD G. . . . . Cornell University, Ithaca, N. Y.  
 FISHER, VERNON J. . . . . Michigan State College, East Lansing, Mich.  
 FLEMING, H. K. . . . . Pennsylvania State College, North East, Pa.  
 FLOATE, RAY . . . . . Michigan Fruit Canners Inc., Benton Harbor, Mich.  
 FLORY, WALTER S. . . . . Blandy Experimental Farm, Boyce, Va.  
 FORD, HARRY W. . . . . Ohio State University, Columbus, Ohio.  
 FORDE, HAROLD I. . . . . University of California, Davis, Calif.  
 FOSLER, GAIL M. . . . . University of Illinois, Urbana, Ill.  
 FOSSUM, M. T. . . . . Cornell University, Ithaca, N. Y.  
 FOSTER, A. A. . . . . Box 327, Sanford, Fla.  
 FRANCIS, JAMES G. . . . . North Carolina State College, Raleigh, N. C.  
 FRANKLIN, D. F. . . . . Branch Experiment Station, Parma, Idaho.  
 FRAZIER, W. A. . . . . University of Hawaii, Honolulu, Hawaii.  
 FREAR, DONALD E. H. . . . . Pennsylvania State College, State College, Pa.  
 FRENCH, A. P. . . . . Massachusetts State College, Amherst, Mass.  
 FRIEND, W. H. . . . . Texas Experiment Station, Weslaco, Tex.  
 FUEGLEIN, J. B. . . . . Richmond, Ind.  
 FULLMER, F. S. . . . . 430 N. Magnolia Ave., Whittier, Calif.  
 FURR, I. R. . . . . Box 737, Indio, Calif.
- GABELMAN, WARREN H. . . . . P. O. Box 1106, New Haven, Conn.  
 GARDNER, F. E. . . . . U. S. Horticultural Laboratory, Orlando, Fla.  
 GARDNER, M. E. . . . . North Carolina State College, Raleigh, N. C.  
 GARRISON, O. B. . . . . Clemson Agricultural College, Clemson, S. C.  
 GAUCH, H. G. . . . . University of Maryland, College Park, Md.  
 GEISE, F. W. . . . . American Can Co., Chicago, Ill.  
 GERHARDT, FISK. . . . . U. S. Dept. Agr., Wenatchee, Wash.  
 GIBSON, R. E. . . . . South Haven, Mich.  
 GILBERT, FRANKLIN A. . . . . 20 Marvin Lane, Univ. Heights, New Brunswick, N. J.  
 GILGUT, C. J. . . . . Waltham Field Sta., Waltham, Mass.  
 GILL, DENZEL L. . . . . Field Laboratory, Springhill, Ala.  
 GILMORE, A. E. . . . . University of California, Davis, Calif.  
 GLENN, D. S. . . . . Box 46, Exeter, Calif.  
 GOPALKRISHNA, N. . . . . University of Illinois, Urbana, Ill.  
 GORDON, FRED M. . . . . Old Court House Annex, Mineola, N. Y.  
 GOSSARD, A. C. . . . . U. S. Horticultural Field Sta., Meridian, Miss.  
 GOULD, WILBUR A. . . . . Ohio State University, Columbus, Ohio.  
 GRAMLING, A. C., JR., MRS. . . . . Box 620, Clemson, S. C.  
 GRAY, G. F. . . . . State Teachers College, Nacogdoches, Texas.  
 GRAY, O. S. . . . . Box 513, Arlington, Texas.  
 GREEN, FERRIS M. . . . . Colorado Experiment Station, Austin, Colo.  
 GREENHILL, A. W. . . . . Boron Agr. Bureau, Harpenden, Herts, England.  
 GREENLEAF, WALTER H. . . . . Alabama Polytechnic Institute, Auburn, Ala.  
 GRIBBINS, M. F. . . . . DuPont Bldg., Wilmington, Del.  
 GRIGGS, WILLIAM H. . . . . University of California, Davis, Calif.  
 GROVE, LARRY C. . . . . Iowa State College, Ames, Iowa.  
 GUENGERICH, H. W. . . . . Stark Bros. Nurseries, Louisiana, Mo.  
 GUSTAFSON, F. G. . . . . University of Michigan, Ann Arbor, Mich.  
 GUYER, R. B. . . . . University of Maryland, College Park, Md.  
 GUZMAN, V. L. . . . . Louisiana State University, Baton Rouge, La.
- HAAS, A. R. C. . . . . Citrus Experiment Station, Riverside, Calif.  
 HABER, E. S. . . . . Iowa State College, Ames, Iowa.  
 HADESELL, D. W. . . . . 104 Westridge Dr., Tallahassee, Florida.  
 HAGLER, T. B. . . . . Alabama Polytechnic Institute, Auburn, Ala.

- HALL, CHESLEY B. . . . . Purdue University, Lafayette, Ind.  
 HALLER, M. H. . . . . Plant Industry Station, Beltsville, Md.  
 HALMA, F. F. . . . . University of California, Los Angeles, Calif.  
 HAM, EDWARD J. . . . . 1011 W. 3rd St., Stillwater, Okla.  
 HAMILTON, JOSEPH. . . . . R. D. 1, Box 449, Yuma, Ariz.  
 HAMNER, CHARLES L. . . . . Michigan State College, East Lansing, Mich.  
 HANKINSON, KENNETH. . . . . 125 King George Road, Pennington, N. J.  
 HANLEY, J. H. . . . . University Arboretum, Seattle, Wash.  
 HANNA, G. C. . . . . University of California, Davis, Calif.  
 HANSEN, CARL J. . . . . University of California, Davis, Calif.  
 HANSEN, ELMER. . . . . Oregon State College, Corvallis, Ore.  
 HARBOUR, F. BRYAN. . . . . Tovrea Packing Co., Box 2010, Phoenix, Arizona.  
 HARDENBURG, E. V. . . . . Cornell University, Ithaca, N. Y.  
 HARDING PAUL L. . . . . 415 N. Parramore St., Orlando, Fla.  
 HARDY, MAX B. . . . . U. S. Dept. Agr., Albany, Ga.  
 HARGRAVE, P. D. . . . . Horticultural Station, Brooks, Alberta.  
 HARLEY, C. P. . . . . Bureau of Plant Industry Station, Beltsville, Md.  
 HARMON, F. N. . . . . U. S. Dept. Agr., Fresno, Calif.  
 HARMON, SILAS A. . . . . Coastal Plain Experiment Station, Tifton, Ga.  
 HARRINGTON, F. M. . . . . University of Montana, Bozeman, Mont.  
 HARRINGTON, J. F. . . . . University of California, Davis, Calif.  
 HARRIS, G. H. . . . . University of British Columbia, Vancouver, B. C.  
 HARRIS, R. W. . . . . University of California, Davis, Calif.  
 HARRISON, C. J. . . . . Tocklai Exp. Sta., Cinnamare P.O. Assam, India.  
 HARRISON, T. B. . . . . Dominion Experiment Station, Harrow, Ontario.  
 HARTMAN, F. O. . . . . 523 Hackett Road, Toledo, Ohio.  
 HARTMAN, JOHN D. . . . . Purdue University, Lafayette, Ind.  
 HARTMANN, H. T. . . . . University of California, Davis, Calif.  
 HARVEY, E. M. . . . . U. S. Dept. Agr., Pomona, Calif.  
 HASEK, RAYMOND F. . . . . Ohio State University, Columbus, Ohio.  
 HAUT, I. C. . . . . University of Maryland, College Park, Md.  
 HAVIS, JOHN R. . . . . Cornell University, Ithaca, N. Y.  
 HAVIS, LEON. . . . . Plant Industry Station, Beltsville, Md.  
 HAWES, JAMES E. . . . . University of Maryland, College Park, Md.  
 HAWTHORN, LESLIE R. . . . . Utah Experiment Station, Logan, Utah.  
 HAWTHORNE, P. L. . . . . Tupelo Chamber of Commerce, Tupelo, Miss.  
 HAYES, W. B. . . . . Agricultural Institute, Allahabad, India.  
 HAYWARD, H. E. . . . . U. S. Salinity Laboratory, Riverside, Calif.  
 HAZEN, M. S. . . . . Milton, New York.  
 HEATON, C. R. . . . . Tyler, Texas.  
 HECHLER, CHARLES, JR. . . . . Box 304, Roslyn, N. Y.  
 HEDLIN, WILLIAM A. . . . . Cornell University, Ithaca, N. Y.  
 HEINICKE, A. J. . . . . New York Experiment Sta., Geneva, N. Y.  
 HEMPHILL, DELBERT D. . . . . University of Missouri, Columbia, Mo.  
 HENDRICKSON, A. H. . . . . University of California, Davis, Calif.  
 HENDRIX, J. WALTER. . . . . University of Hawaii, Honolulu, T. H.  
 HEPLER, J. R. . . . . University of New Hampshire, Durham, N. H.  
 HERMAN, J. R. . . . . 1160 Cragmont Ave., Berkeley, Calif.  
 HERNANDEZ, TEME P. . . . . University of Wisconsin, Madison, Wisc.  
 HESSE, C. O. . . . . University of California, Davis, Calif.  
 HESTER, J. B. . . . . Riverton, N. J.  
 HEWETSON, F. N. . . . . Pennsylvania State College, Arendtsville, Pa.  
 HEWITT, W. B. . . . . University of California, Davis, Calif.  
 HIBBARD, A. D. . . . . University of Missouri, Columbia, Mo.  
 HIKIDA, ROBERT H. . . . . University of Manitoba, Winnipeg, Manitoba.  
 HILDEBRAND, E. M. . . . . Texas A. & M. College, College Station, Tex.  
 HILDRETH, A. C. . . . . Cheyenne Horticultural Station, Cheyenne, Wyo.  
 HILL, ROBERT G., JR. . . . . University of Maryland, College Park, Md.  
 HILLS, WALTER A. . . . . Louisiana Polytechnic Institute, Ruston, La.  
 HILTON, R. J. . . . . University of Alberta, Edmonton, Alberta.  
 HINRICHES, HERMAN. . . . . Oklahoma A. & M. College, Stillwater, Okla.  
 HIROSHIGE, H. M. . . . . University of Hawaii, Honolulu, T. H.  
 HITCHECOCK, A. E. . . . . Boyce-Thompson Institute, Yonkers, N. Y.  
 HITT, C. W. . . . . University of Maine, Orono, Me.

- HOADLEY, ALFRED . . . . . Riverton, N. J.  
 HOAGLAND, D. R. . . . . University of California, Berkeley, Calif.  
 HODGSON, R. W. . . . . University of California, Los Angeles, Calif.  
 HOFFMAN, I. C. . . . . Ohio Experiment Station, Wooster, Ohio.  
 HOFFMAN, J. C. . . . . Everglades Experiment Station, Belle Glade, Fla.  
 HOFFMAN, M. B. . . . . Cornell University, Ithaca, N. Y.  
 HOFFMAN, ROBERT M. . . . . University of California, Red Bluff, Calif.  
 HOLADAY, J. A. . . . . Box 1005, Eugene, Ore.  
 HOLLAR, VICTOR E. . . . . Fordhook Farms, Doylestown, Pa.  
 HOLLEY, W. D. . . . . A. N. Pierson, Inc., Cromwell, Conn.  
 HOLMES, ARTHUR . . . . . Basking Ridge, N. J.  
 HOPE, CLAUDE . . . . . Apt. 18, Turrialba, Costa Rica.  
 HOPP, RICHARD . . . . . Vermont Experiment Station, Burlington, Vt.  
 HORN, ANTON S. . . . . University of Idaho, Boise, Idaho.  
 HORSFALL, FRANK, JR. . . . . Virginia Experiment Station, Blacksburg, Va.  
 HOUGH, L. F. . . . . University of Illinois, Urbana, Ill.  
 HOUGH, W. S. . . . . Winchester Research Lab., Winchester, Va.  
 HOWARD, F. L. . . . . Rhode Island Experiment Sta., Kingston, R. I.  
 HOWARD, W. L. . . . . University of California, Davis, Calif.  
 HOWE, G. H. . . . . New York State Experiment Sta., Geneva, N. Y.  
 HOWELL, M. J. . . . . Bishop College, Marshall, Texas.  
 HOWLAND, JOSEPH E. . . . . Better Homes and Gardens, Des Moines, Iowa.  
 HOWLETT, F. S. . . . . Ohio Experiment Station, Wooster, Ohio.  
 HOWLETT, L. M. . . . . Westbank, British Columbia.  
 HUBBARD, LEON V. . . . . Hillsboro, Ore.  
 HOYLE, BURTON J. . . . . Tulalake Experiment Station, Tulalake, Calif.  
 HUBERTY, M. R. . . . . University of California, Los Angeles, Calif.  
 HUDSON, N. D. . . . . Federal Building, Fresno, Calif.  
 HUELSEN, W. A. . . . . University of Illinois, Urbana, Ill.  
 HUFFINGTON, J. M. . . . . R. 2, Biglerville, Pa.  
 HUGHES, M. B. . . . . Edisto Experiment Station, Blackville, S. C.  
 HUME, E. P. . . . . U. S. Dept. Agri., Mayaguez, Puerto Rico.  
 HUNKLE, V. H. . . . . 797 N. Milwaukee, St., Milwaukee, Wis.  
 HUNT, F. C. . . . . 2202 Jules Street, St. Joseph, Mo.  
 HUTCHINS, A. E. . . . . University of Minnesota, St. Paul, Minn.  
 HUTCHINS, L. M. . . . . Plant Industry Station, Beltsville, Md.  
  
 ISAAC, E. E. . . . . Montana State College, Bozeman, Mont.  
 ISBELL, C. L. . . . . Alabama Polytechnic Institute, Auburn, Ala.  
 ISBIT, ARTHUR . . . . . Cornell University, Ithaca, N. Y.  
 ISVAN, AHMET . . . . . University of California, Davis, Calif.  
 IVANOFF, S. S. . . . . Mississippi Agricultural Experiment Station, State College, Miss.  
 IVERSON, VINCENT E. . . . . University of Montana, Bozeman, Mont.  
  
 JACOB, H. E. . . . . University of California, Davis, Calif.  
 JACOB, WALTER C. . . . . Long Island Vegetable Res. Farm, Riverhead, N. Y.  
 JACOBS, H. L. . . . . Kent, Ohio.  
 JAMISON, F. S. . . . . University of Florida, Gainesville, Fla.  
 JAMES, B. E. . . . . University of Florida, Gainesville, Fla.  
 JENKINS, J. M., JR. . . . . North Carolina Veg. Res. Lab., Wilmington, N. C.  
 JENKINS, W. F. . . . . University of Maryland, College Park, Md.  
 JOHANNESSEN, GEORGE A. . . . . Purdue University, Lafayette, Ind.  
 JOHN, CHARLES A. . . . . Associated Seed Growers, Franklin, Ind.  
 JOHNSON, C. C. . . . . 171 Liberty St., New York City.  
 JOHNSON, W. A. . . . . 242 S. Gay St., Auburn, Ala.  
 JOHNSTON, E. C. . . . . Chas. H. Lilly Co., Albany, Ore.  
 JOHNSTON, J. C. . . . . Citrus Experimental Station, Riverside, California.  
 JOHNSTON, STANLEY . . . . . Michigan Experiment Station, South Haven, Mich.  
 JOHNSTONE, FRANCIS E. . . . . 618 Wilson Bldg., Dallas, Texas.  
 JOLEY, L. E. . . . . Box 1040, Chico, Calif.  
 JONES, F. D. . . . . Ambler, Pa.  
 JONES, H. A. . . . . Plant Industry Station, Beltsville, Md.  
 JONES, L. E. . . . . 1059 Pine St., Redding, Calif.

- JONES, L. H. . . . . Massachusetts State College, Amherst, Mass.  
 JONES, ROBERT E. . . . . Church Grape Juice Co., Kennewick, Wash.  
 JONES, ROBERT W. . . . . Citrus Experiment Station, Lake Alfred, Fla.  
 JONES, S. E. . . . . Texas Agr. Exp. Sta., College Station, Texas.  
 JONES, T. H. . . . . University of Tennessee, Knoxville, Tenn.  
 JONES, WINSTON W. . . . . Citrus Experiment Station, Riverside, Calif.  
 JUDKINS, W. P. . . . . Ohio Experiment Station, Wooster, Ohio.  
 JUNGEMAN, A. A. . . . . Box 1028, Modesto, Calif.
- KALIN, ELWOOD W. . . . . Washington State College, Pullman, Wash.  
 KALMAR, A. F. . . . . Food Machinery Corporation, Riverside, Calif.  
 KAMEMOTO, HARUYUKI . . . . 107 Harvard Place, Ithaca, N. Y.  
 KAMP, JAMES R. . . . . University of Illinois, Urbana, Ill.  
 KAPULER, B. . . . . Mikveh-Israel Agr. Sta., Tel-Aviv, Palestine.  
 KARR, CHADWICK. . . . . Route 7, Yakima, Wash.  
 KASIMATIS, AMANDUS N. . . . West Hall, Davis, Calif.  
 KASS, MIRYAM Z. . . . . Kibbutz Gimel, Rishon LeZion, Palestine.  
 KATYAL, SHAM LAL. . . . . Central College of Agrl. & Forestry New Delhi, India.  
 KAYS, W. R. . . . . Agricultural Experiment Station, Stillwater, Okla.  
 KEENER, R. L. . . . . University of Georgia, Athens, Ga.  
 KEIRNS, V. E. . . . . RFD 1, Amesville, O.  
 KELLEY, C. B. . . . . Horticulture Experiment Station, Vineland Sta., Ontario.
- KELLY, EDWIN J. . . . . University of Maryland, College Park, Md.  
 KELLY, WILLIAM C. . . . . U. S. Plant, Soil & Nut. Lab., Ithaca, N. Y.  
 KELSALL, A. . . . . Supt. Exp. Sta., Kentville, N. S.  
 KENWORTHY, ALVIN L. . . . . Michigan State College, East Lansing, Mich.  
 KERR, W. L. . . . . Dominion Forestry Substation, Sutherland, Sask.  
 KESSLER, GEORGE M. . . . . Michigan State College, East Lansing, Mich.  
 KHAN, FAZLUR RAHIM. . . . . Univ. Farm Campus, St. Paul, Minn.  
 KIENHOLZ, J. R. . . . . U. S. Fruit Disease Laboratory, Hood River, Ore.  
 KIKUTA, K. . . . . University of Hawaii, Honolulu, T. H.  
 KIMBALL, M. H. . . . . 524 No. Spring St., Los Angeles, Calif.  
 KIMBROUGH, W. D. . . . . Louisiana State University, University, La.  
 KING, J. R. . . . . Brunswick Hotel, Boston, Mass.  
 KINMAN, C. F. . . . . Plant Industry Station, Beltsville, Md.  
 KIPLINGER, D. C. . . . . Ohio State University, Columbus, Ohio.  
 KITCHEN, E. M. . . . . 51 Madison Ave., New York City.  
 KLOTZBACH, CARROL L. . . . . Box 55, Kendall, Fla.  
 KNOTT, J. E. . . . . University of California, Davis, Calif.  
 KNOWLES, JOHN T. . . . . Libby, McNeill & Libby, Blue Island, Ill.  
 KOFRANEK, ANTON M. . . . . Cornell University, Ithaca, N. Y.  
 KOHNER, BERTHA E. . . . . 3212 Northampton St., N. W., Washington, D. C.  
 KOUDAL, ELIZABETH. . . . . Box 55, LaConner, Wash.  
 KRAMER, AMIHUD. . . . . 30 D. Crescent Road, Greenbelt, Md.  
 KRANTZ, F. A. . . . . University of Minnesota, St. Paul, Minn.  
 KRAUS, E. J. . . . . University of Chicago, Chicago, Ill.  
 KRAUS, J. E. . . . . University of Idaho, Moscow, Ida.  
 KREZDORN, A. H. . . . . A. & M. College of Texas, College Station, Texas.  
 KRISHNAMURTHI, S. . . . . Michigan State College, East Lansing, Mich.  
 KROMACHAL, ARNOLD. . . . . New Mexico College, State College, N. M.  
 KUNKEL, ROBERT. . . . . Colorado A. & M. College, Ft. Collins, Colo.
- LACHMAN, WM. H. . . . . University of Massachusetts, Amherst, Mass.  
 LAGASSE, F. S. . . . . U. S. Field Lab. for Tung Invest., Gainesville, Fla.  
 LAMB, ROBERT C. . . . . University of Minnesota, St. Paul, Minn.  
 LAMBETH, VICTOR N. . . . . University of Minnesota, Columbia, Mo.  
 LANA, EDWARD P. . . . . Iowa State College, Ames, Iowa.  
 LONDON, R. H. . . . . University of Minnesota, St. Paul, Minn.  
 LANTZ, HARVEY L. . . . . Iowa State College, Ames, Iowa.  
 LARSEN, EJNAR C. . . . . University of Idaho, Moscow, Idaho.  
 LARSON, RUSSELL. . . . . Pennsylvania State College, State College, Pa.  
 LASSITER, JUDSON H. . . . . Box 2817, University Station, Gainesville, Fla.  
 LATIMER, L. P. . . . . University of New Hampshire, Durham, N. H.

- LAVOIE, J. H. . . . . Department of Agriculture, Quebec, Canada.  
 LEACH, HON. WILL. . . . . Judges Chambers, Scranton, Pa.  
 LECLERG, E. L. . . . . 1724 F. St., N. W., Washington 25, D. C.  
 LECRONE, FRED. . . . . Oklahoma A & M College, Stillwater, Okla.  
 LEE, SHU HSIEN. . . . . 403 Ann Street, East Lansing, Mich.  
 LENZ, FRED. . . . . R. D. 1, Box 279, Homestead, Fla.  
 LEONARD, O. A. . . . . Mississippi Experiment Sta., State College, Miss.  
 LEFAGE, RENE. . . . . Ingenieur-Agr. E. S. A., 45 Rue Chevre, Angers,  
     M. & L. France.  
 LEPORE, ARMANDO. . . . . Wyoming, Del.  
 LESLEY, J. W. . . . . Citrus Experiment Station, Riverside, Calif.  
 LESLIE, E. H. . . . . Traver Road, Ann Arbor, Mich.  
 LESLIE, W. R. . . . . Experiment Station, Morden, Manitoba.  
 LESSARD, PIERRE. . . . . Frelightsburg, Missisquoi-City, Quebec, Canada.  
 LEVERING, S. R. . . . . Ararat, Va.  
 LEWIS, F. H. . . . . Fruit Research Laboratory, Arendtsville, Pa.  
 LEWIS, MILTON T. . . . . Pennsylvania State College, State College, Pa.  
 LILLELAND, OMUND. . . . . University of California, Davis, Calif.  
 LINDNER, R. C. . . . . 1009 Vassar St., Wenatchee, Wash.  
 LINK, CONRAD B. . . . . Brooklyn Botanic Garden, Brooklyn, N. Y.  
 LLOYD, J. W. . . . . 524 N. San Gabriel Blvd., San Gabriel, Calif.  
 LOBENSTEIN, —. —. . . . . Kansas State College, Manhattan, Kans.  
 LOCKE, L. F. . . . . U. S. Dept. Agr., Woodward, Okla.  
 LOEWING, W. F. . . . . University of Iowa, Iowa City, Ia.  
 LONG, D. D. . . . . 20 N. Wacker Drive, Chicago, Ill.  
 LONG, E. M. . . . . Continental Mexican Rubber Co., Torreon, Mex.  
 LONGLEY, L. E. . . . . University of Minnesota, St. Paul, Minn.  
 LOMIS, N. H. . . . . U. S. Horticultural Station, Meridian, Miss.  
 LOOMIS, W. E. . . . . Iowa State College, Ames, Ia.  
 LORENZ, O. A. . . . . University of California, Davis, Calif.  
 LORZ, ALBERT P. . . . . Purdue University, Lafayette, Ind.  
 LOTT, RICHARD V. . . . . University of Illinois, Urbana, Ill.  
 LOTT, W. L. . . . . North Carolina Agriculture Experiment Station,  
     Raleigh, N. C.  
 LOUSTALOT, ARNAUD J. . . . . U. S. Dept. Agr., Mayaguez, Puerto Rico.  
 LOWMAN, M. S. . . . . Plant Industry Station, Beltsville, Md.  
 LUCAS, I. B. . . . . Markdale, Ontario.  
 LUCE, W. A. . . . . Yakima, Wash.  
 LUMSDEN, D. V. . . . . 8700 Colesville Rd., Silver Spring, Md.  
 LUTZ, J. M. . . . . U. S. Horticultural Station, Meridian, Miss.  
 LYON, A. V. . . . . Commonwealth Research Sta., Merbein, Australia.  
 LYON, C. B. . . . . Hawaiian Pineapple, Co. Honolulu, T. H.  
 LYONNAIS, S. A. . . . . Bruxelles, Belgium.  
 MACDANIELS, L. H. . . . . Cornell University, Ithaca, N. Y.  
 MACGILLIVRAY, J. H. . . . . University of California, Davis, Calif.  
 MACQUEEN, J. W. . . . . Jefferson & Hillman Hospitals, Birmingham, Ala.  
 MCCARTNEY, JAMES S. . . . . University of Minnesota, St. Paul, Minn.  
 MCCCLINTOCK, J. A. . . . . Purdue University, Lafayette, Ind.  
 MCCOLLAM, MILLARD, E. . . . . 416 Beans Bldg., San Jose, Calif.  
 MCCOLLUM, JOHN P. . . . . University of Illinois, Urbana, Ill.  
 MCCORMICK, A. C. . . . . 4327 N. E. Glisan St., Portland, Oregon.  
 MCCUBBIN, E. N. . . . . University of Florida, Hastings, Fla.  
 MCCUE, CHARLES P., JR. . . . . Appledore Orchard, Greenwood, Va.  
 MCDANIEL, J. C. . . . . 403 State Office Bldg., Nashville, Tenn.  
 MCELROY, LEONA A. . . . . Rhode Island State College, Kingston, R. I.  
 MCELWEE, E. W. . . . . Mississippi State College, State College, Miss.  
 MCGINTY, R. A. . . . . South Carolina Experiment Station, Clemson, S. C.  
 MCGOLDRICK, FRED. . . . . Cornell University, Ithaca, N. Y.  
 MCHATTON, T. H. . . . . Georgia State College, Athens, Ga.  
 MCKAY, JOHN W. . . . . Plant Industry Station, Beltsville, Md.  
 MCLEAN, J. G. . . . . Kern Co., Bakersfield, Calif.  
 MCELLELLAN, P. I. . . . . E. W. McLellan Co., Colma, Calif.



- McMAHAN, J. E. . . . . University of Tennessee, Junior College, Martin, Tenn.
- McMAHON, M. L. . . . . Box 112, Lanai City, Hawaii.
- McMUNN, R. L. . . . . University of Illinois, Urbana, Ill.
- McNAMEE, R. W. . . . . Carbide & Carbon Chem. Corp., N. Y. City.
- MACK, W. B. . . . . Pennsylvania State College, State College, Pa.
- MAGISTAD, O. C. . . . . U. S. Regional Salinity Lab., Riverside, Calif.
- MAGNESS, J. R. . . . . Plant Industry Station, Beltsville, Md.
- MAGOON, C. A. . . . . 4308 Queensbury Road, Riverdale, Md.
- MAGRUDER, ROY. . . . . Plant Industry Station, Beltsville, Md.
- MAHONEY, C. H. . . . . National Cannery Ass'n., Washington, D. C.
- MAJEWSKI, F. . . . . College of Agriculture, Rakowieckah 8, Warsaw, Poland.
- MALLISON, E. D. . . . . Atlantic Commission Co., New York City.
- MANN, LOUIS K. . . . . University of California, Davis, Calif.
- MARKS, RICHARD T. . . . . California Packing Corp., Merced, Calif.
- MARSH, R. S. . . . . University of West Virginia, Morgantown, W. Va.
- MARSHALL, R. E. . . . . Michigan State College, East Lansing, Mich.
- MARTH, PAUL C. . . . . Plant Industry Station, Beltsville, Md.
- MARTIN, D. . . . . P. O. Box 109, Canberra City, A. C. T. Australia.
- MARTIN, J. A., JR. . . . . South Carolina Experiment Station, Clemson, S. C.
- MARTIN, WM. B. . . . . University of California, Berkeley, Calif.
- MATHER, T. H. . . . . 506 Marine Bldg., Vancouver, B. C.
- MATHEWS, E. L. . . . . Plymouth, Fla.
- MATHISEN, S. S. . . . . 9722 Watertown Plank Rd., Milwaukee, Wisc.
- MATKIN, O. A. . . . . Agricultural Laboratory, P. O. Box 308, Orange, Calif.
- MATSUURA, MINORU. . . . . P. O. Box 1882, Hilo, Hawaii.
- MATTSON, HAROLD. . . . . North Dakota State College, Fargo, N. D.
- MATTUS, G. E. . . . . Cornell University, Ithaca, N. Y.
- MEADER, E. M. . . . . Pittsfield, N. H.
- MECARTNEY, J. L. . . . . Pennsylvania State College, State College, Pa.
- MECCA, SEBASTIAN. . . . . 2346 Sedgley Ave., Philadelphia, Pa.
- MEHLQUIST, G. A. L. . . . . Missouri Botanical Garden, St. Louis, Mo.
- MEISS, ALFRED N. . . . . 114 Whitney Ave., New Haven, Conn.
- MENDALL, SEATON C. . . . . Hammondsport, N. Y.
- MERO, ROBERT S. . . . . Hampton Institute, Hampton, Va.
- MERRILL, GRANT. . . . . Red Bluff, Calif.
- MERRILL, SAMUEL, JR. . . . . U. S. Tung Laboratory, Bogalusa, La.
- MERRILL, T. A. . . . . Washington State College, Pullman, Wash.
- METCALF, HOMER N. . . . . University of Montana, Bozeman, Mont.
- MEYER, ARTHUR. . . . . University of Tennessee, Knoxville, Tenn.
- MICHAEL, RALPH. . . . . Texas Experiment Station, Gilmer, Tex.
- MICHALESKI, L. A. . . . . Highways Branch, Legislative Bldg., Winnipeg, Can.
- MILLER, CLOY M. . . . . Barberton, Ohio.
- MILLER, J. C. . . . . Louisiana State University, University, La.
- MILLER, VICTOR J. . . . . Agricultural Experiment Station, Urbana, Ill.
- MILLIKAN, DANIEL F. . . . . University of Missouri, Columbia, Mo.
- MILNE, C. G. . . . . Purdue University, Lafayette, Ind.
- MINGES, P. A. . . . . University of California, Davis, Calif.
- MITCHELL, A. E. . . . . Michigan State College, East Lansing, Mich.
- MOLL, ALVIN C. . . . . Ohio State University, Columbus, Ohio.
- MOLTENO, E. B. F. . . . . Glen Elgin, Elgin C. P., South Africa.
- MOON, HUBERT H. . . . . Plant Industry Station, Beltsville, Md.
- MOORE, E. C. . . . . 621 S. Divisadero, Visalia, Calif.
- MOORE, J. G. . . . . University of Wisconsin, Madison, Wis.
- MOORE, PAUL W. . . . . Box 30, Azusa, Calif.
- MOORE, ROBERT C. . . . . Virginia Experiment Station, Blacksburg, Va.
- MOORE, RUFUS H. . . . . University of Nebraska, Lincoln, Nebr.
- MOORE, W. D. . . . . 501 S. Andrews Ave., Ft. Lauderdale, Fla.
- MORAES, ANTONIO DE MATOS. . . . . University of Lisbon, Lisboa, Portugal.
- MORRIS, H. F. . . . . Texas Experiment Station, Nacogdoches, Tex.
- MORRIS, L. L. . . . . University of California, Davis, Calif.
- MORROW, E. B. . . . . North Carolina State College, Raleigh, N. C.
- MORTENSEN, E. . . . . Texas Experiment Station, Winter Haven, Tex.

- MOWRY, HAROLD . . . . . University of Florida, Gainesville, Fla.  
 MULLIGAN, BRIAN O. . . . . University of Washington, Seattle, Wash.  
 MULLISON, W. R. . . . . 2010 Ashman St., Midland, Mich.  
 MUNGER, H. M. . . . . Cornell University, Ithaca, N. Y.  
 MURNEEK, A. E. . . . . University of Missouri, Columbia, Mo.  
 MURPHY, PAUL . . . . . 8 Stanley Rd., Oxford, England.  
 MUSSER, A. M. . . . . College of Agriculture, Clemson, S. C.  
 MUSSER, JAMES L. . . . . Charter Seed Co., Twin Falls, Idaho.  
 MYHRE, ARTHUR . . . . . Western Washington Experiment Sta., Puyallup, Wash.  
  
 NATIVIDADE, J. VIEIRA . . . . . Alcobaca, Portugal.  
 NEARPASS, D. C. . . . . 1860 W. Leon, Gainesville, Fla.  
 NEARY, M. E. . . . . Dept. Agriculture & Marketing, Truro, Nova Scotia.  
 NEFF, MARSHALL S. . . . . Box 298, Cairo, Ga.  
 NETTLES, V. F. . . . . University of Florida, Gainesville, Fla.  
 NEW, EARL H. . . . . University of Idaho, Moscow, Idaho.  
 NEWCOMB, D. ALBERT . . . . . Foothill Laboratory, Corona, Calif.  
 NEWCOMB, RALPH V. . . . . P. O. Box 144, Yuba City, Calif.  
 NIGHTINGALE, G. T. . . . . Pineapple Research Inst., Honolulu, Hawaii.  
 NIXON, ROY W. . . . . U. S. Dept. Agr. Indio, Calif.  
 NIXON, WALTER H. . . . . 98 Zabola Rd., Salinas, Calif.  
 NOLL, C. J. . . . . Pennsylvania State College, State College, Pa.  
 NORDINE, ROY M. . . . . The Morton Arboretum, Lisle, Ill.  
 NORDLINGER, E. W. . . . . The Food Packer, 139 N. Clark St., Chicago, Ill.  
 NORTHUP, RAYMOND C. . . . . Forest Ave., Newport, R. I.  
 NYLUND, R. E. . . . . University of Minnesota, St. Paul, Minn.  
  
 OBERLE, GEORGE . . . . . New York State Experiment Sta., Geneva, N. Y.  
 O'BRIEN, WASH. R. . . . . 191 Mich. Sta., Benton Harbor, Mich.  
 OCHSE, J. J. . . . . University of Miami, Miami, Fla.  
 ODLAND, M. L. . . . . Pennsylvania State College, State College, Pa.  
 OGLE, ROBERT E. . . . . University of Tennessee Exp. Sta., Knoxville, Tenn.  
 OLMO, H. P. . . . . University of California, Davis, Calif.  
 OLNEY, A. J. . . . . University of Kentucky, Lexington, Ky.  
 OPITZ, KARL . . . . . Camarillo, Calif.  
 OPPENHEIMER, H. R. . . . . Agriculture Research Station, Rehovot, Palestine.  
 O'REILLY, H. J. . . . . The Dalles Experimental Area, The Dalles, Oregon.  
 O'ROURKE, FRANCIS L. . . . . Michigan State College, East Lansing, Mich.  
 ORR, HENRY P. . . . . Auburn Polytechnic Institute, Auburn, Ala.  
 OSENT, JEANNE . . . . . J. T. Baker Chem. Co., Phillipsburg, N. J.  
 OSUNA, PEDRO . . . . . College of Agriculture, Rio Piedras, Puerto Rico.  
 OVERCASH, J. P. . . . . Mississippi State College, State College, Miss.  
 OVERHOLSER, E. L. . . . . Virginia Polytechnic Institute, Blacksburg, Va.  
 OVERLEY, F. L. . . . . Fruit Branch Experiment Station, Wenatchee, Wash.  
  
 PADDOCK, ELTON F. . . . . Ohio State University, Columbus, Ohio.  
 PAGE, E. M. . . . . 101 Chouteau Ave., St. Louis, Mo.  
 PAINTER, J. H. . . . . U. S. Tung Laboratory, Cairo, Ga.  
 PALMER, E. F. . . . . Vineland Station, Ontario, Canada.  
 PALMER, R. C. . . . . Experiment Station, Summerland, B. C.  
 PALMITER, D. H. . . . . Experiment Station, Poughkeepsie, N. Y.  
 PANCOAST, HARRY M. . . . . San José, Calif.  
 PAPAIOANNOU, P. . . . . University of California, Davis, Calif.  
 PARKER, E. R. . . . . Citrus Experiment Station, Riverside, Calif.  
 PARKER, M. M. . . . . Virginia Truck Station, Norfolk, Va.  
 PARMENTER, READ . . . . . Suncook, N. H.  
 PARTIDGE, N. L. . . . . Michigan State College, East Lansing, Mich.  
 PATEL, G. I. . . . . University of California, Davis, Calif.  
 PAUR, SHERMAN . . . . . 606 S. Allen St., State College, Pa.  
 PEACOCK, N. D. . . . . University of Tennessee, Knoxville, Tenn.  
 PEARSON, HAROLD E. . . . . Box 38, LaVerne, Calif.  
 PEARSON, OSCAR H. . . . . Farmers Exch. Box 1482, West Springfield, Mass.  
 PEIRCE, L. C. . . . . Elgin Co-op. Fruitgrowers Ltd., Box 21, Elgin, C. P.

- PELKEY, ROBERT D. . . . . University of Nebraska, Lincoln, Neb.  
 PELTON, W. C. . . . . University of Tennessee, Knoxville, Tenn.  
 PENTZER, W. T. . . . . U. S. Horticulture Field Sta., Fresno, Calif.  
 PERLMUTTER, FRANK. . . . . 346 Broadway, New York City.  
 PERRY, VERNON G. . . . . 260 S. Gay St., Auburn, Ala.  
 PETERS, ROBERT B. . . . . 739 N. 7th St., Allentown, Pa.  
 PETERSON, C. E. . . . . Iowa Agricultural Experiment Station, Ames, Iowa.  
 PETERSON, LEWIS E. . . . . Muscatine Island Field Sta., Fruitland, Iowa.  
 PHILLIPS, ROBERT A. . . . . University of Minnesota, St. Paul, Minn.  
 PICKETT, A. D. . . . . Entomological Lab., Annapolis Royal, Nova Scotia.  
 PICKETT, BARZILLAI S. . . . . University of Georgia, Athens, Ga.  
 PICKETT, W. F. . . . . Kansas State College, Manhattan, Kans.  
 PIENIAZEK, S. A. . . . . Institute of Pomology, Osado Palocowa, Skierniewice, Poland.  
 PIRINGER, ALBERT A., JR. . . . . University of Minnesota, St. Paul, Minn.  
 PLACE, RUTH MOSHER. . . . . Garden Editor, Detroit News, Detroit, Mich.  
 PLATENIUS, HANS. . . . . Estacion Central de Colonizacion, en Tingo Maria, via Lima, Peru.  
 POESCH, G. H. . . . . 1741 Cardiff Road, Columbus, Ohio.  
 POLLARD, LEONARD H. . . . . Utah State College, Logan, Utah.  
 POOLE, C. F. . . . . University of Hawaii, Honolulu, T. H.  
 POPENOE, WILSON. . . . . Escuelaffi Agricola Panamericana, Tegucigalpa, Honduras, C. A.  
 PORTER, ALTON M. . . . . 22 Manor Circle, Takoma Park, Md.  
 PORTER, D. R. . . . . Campbell Soup Co., Sacramento, Calif.  
 POST, KENNETH. . . . . Cornell University, Ithaca, N. Y.  
 POTTER, G. F. . . . . U. S. Tung Laboratory, Bogalusa, La.  
 POWERS, LEROY. . . . . Box 1250, Cheyenne, Wyo.  
 PRATT, A. N. . . . . Box 1202, Roanoke, Va.  
 PRATT, HARLAN K. . . . . University of California, Davis, Calif.  
 PRIDHAM, ALFRED M. S. . . . . Cornell University, Ithaca, N. Y.  
 PROEBSTING, E. L. . . . . University of California, Davis, Calif.  
 PROEBSTING, EDWARD L. . . . . 113 1st St., Davis, Calif.  
 PRUSHEK, E. . . . . Rt. 3, Niles, Mich.  
 PRYOR, DEAN E. . . . . 3630 E. Colorado St., Pasadena, Calif.  
 PYLE, ROBERT. . . . . West Grove, Pa.  
 QAZILBASH, N. A. . . . . Islamia College, Peshawar, N.W.F.P. India.  
 RADHAVA, RAO S. . . . . Dept. Agri., Ootacamund, S. India.  
 RAGLAND, C. H. . . . . Mississippi State College, State College, Miss.  
 RAHMLow, H. J. . . . . 1532 University Ave., Madison, Wis.  
 RAHN, E. M. . . . . University of Delaware, Newark, Dela.  
 RAISINGHANI, B. R. . . . . Korachi, Pakistan, India.  
 RALEIGH, G. J. . . . . Cornell University, Ithaca, N. Y.  
 RANDALL, THOMAS E. . . . . Washington State College, Pullman, Wash.  
 RANDHAWA, G. S. . . . . Michigan State College, East Lansing, Mich.  
 RANDOLPH, U. A. . . . . Texas Agricultural Experiment Station, Montague, Texas.  
 RASMUSSEN, E. J. . . . . University of New Hampshire, Durham, N. H.  
 RAWLINGS, C. O. . . . . Oregon State College, Corvallis, Oregon.  
 RAYNER, S. H. . . . . Salisbury, Md.  
 REECE, P. C. . . . . 415 N. Parramore St., Orlando, Fla.  
 REED, C. A. . . . . Plant Industry Station, Beltsville, Md.  
 REED, H. J. . . . . Purdue University, Lafayette, Ind.  
 REED, H. M. . . . . Texas Experiment Station, Angleton, Tex.  
 REEVES, E. L. . . . . Box 99, Wenatchee, Wash.  
 REGER, M. W. . . . . California Packing Corp., Toppenish, Wash.  
 REIDER, ALFRED. . . . . Arnold Arboretum, Jamaica Plain, Mass.  
 REIMER, C. A. . . . . South Haven, Mich.  
 REIMER, F. C. . . . . Experiment Station, Medford, Ore.  
 REITER, VICTOR. . . . . 1195 Stanyan St., San Francisco, Calif.  
 RELYEA, KENNETH E. . . . . Farmers Seed and Nursery Co., Fairbault, Minn.  
 REUTHER, WALTER. . . . . 415 N. Parramore St., Orlando, Fla.

- REYNARD, G. B. . . . . Campbell Soup Co., Riverton, N. J.  
 RIBBE, JOHN. . . . . Malott, Wash.  
 RICHARDSON, H. B. . . . . 3864 Ramona St., Riverside, Calif.  
 RICK, C. M. . . . . University of California, Davis, Calif.  
 RIDGWAY, H. W. . . . . Mickleton, N. J.  
 RILEY, HARLAND K. . . . . Box 44, S. L. I, Lafayette, Louisiana.  
 RINER, MARY EDITH. . . . . Stanford, University, Palo Alto, Calif.  
 RIOLLANO, ARTURO. . . . . Agricultural Experiment Substation, Isabela, P. R.  
 RIVERO, M. J. . . . . Dept. Ministerio de la Economia Nacional, Bogata, Columbia, S. A.  
 RIZZI, A. D. . . . . Visalia, Calif.  
 ROBBINS, W. REI. . . . . New Jersey Experiment Sta., New Brunswick, N. J.  
 ROBERTS, A. N. . . . . Oregon State College, Corvallis, Ore.  
 ROBERTS, EDITH A. . . . . Vassar College, Poughkeepsie, N. Y.  
 ROBERTS, JOHN W. . . . . 116 D. Park Ave., Winter Park, Fla.  
 ROBERTS, O. C. . . . . 24 Nutting Ave., Amherst, Mass.  
 ROBERTS, R. H. . . . . University of Wisconsin, Madison, Wis.  
 ROBERTSON, W. H. . . . . Department of Agriculture, Victoria, B. C.  
 ROESSLER, E. B. . . . . University of California, Davis, Calif.  
 ROEVER, W. E. . . . . 97 Lafayette St., Stamford, Conn.  
 ROGERS, B. L. . . . . University of Maryland, College Park, Md.  
 ROLLINS, C. F. . . . . P. O. Box 981 Clearwater, Fla.  
 ROLLINS, H. A. . . . . University of Connecticut, Storrs, Conn.  
 ROMBERG, L. D. . . . . U. S. Pecan Field Sta., Brownwood, Tex.  
 ROMSHE, F. A. . . . . Oklahoma A. & M. College, Stillwater, Okla.  
 ROQUETA, RAMON SALA. . . . Patronato de Biologia Aplicada de Bon Repos, Diputacion, Lerida, Spain.  
 ROSE, DEAN H. . . . . U. S. Dept. Agr., Washington, D. C.  
 ROSE, J. W. . . . . Michigan State College, East Lansing, Mich.  
 RUSSELL, C. E. . . . . Michigan State College, East Lansing, Mich.  
 RUTH, W. A. . . . . University of Illinois, Urbana, Ill.  
 RYALL, A. LLOYD. . . . . Box 1425, Harlingen, Tex.  
 RYERSON, K. A. . . . . University of California, Davis, Calif.  
 RYGG, G. LEONARD. . . . . U. S. Hort. Field Lab., Pomona, Calif.
- SAMISCH, RUDOLF. . . . . Agricultural Experiment Sta., Rehoboth, Palestine.  
 SAVAGE, E. F. . . . . Georgia Experiment Station, Experiment, Ga.  
 SAX, KARL. . . . . Bussey Institute, Forest Hills, Mass.  
 SAYRE, C. B. . . . . New York State Experiment Station, Geneva, N. Y.  
 SCHAEFER, A. J. . . . . Route 32, Newburgh, N. Y.  
 SCHERMERHORN, L. G. . . . . New Jersey Experiment Sta., New Brunswick, N. J.  
 SCHMIDT, ROBERT. . . . . North Carolina State College, Raleigh, N. C.  
 SCHNEIDER, G. W. . . . . Rutgers University, New Brunswick, N. J.  
 SCHOONOVER, W. R. . . . . University of California, Berkeley, Calif.  
 SCHRADER, A. L. . . . . University of Maryland, College Park, Md.  
 SCHRADER, OTTO LYRA. . . . Copacabana, Rio de Janeiro, Brazil.  
 SCHROEDER, C. A. . . . . University of California, Los Angeles, Calif.  
 SCHROEDER, RAYMOND A. . . . University of Missouri, Columbia, Mo.  
 SCHUBERT, OSCAR E. . . . . University of Illinois, Urbana, Ill.  
 SCHULTZ, J. H. . . . . Prosser, Wash.  
 SCHUSTER, C. E. . . . . Oregon State College, Corvallis, Ore.  
 SCHWARTZ, C. D. . . . . Western Washington Exp. Sta., Puyallup, Wash.  
 SCOTT, D. H. . . . . Plant Industry Station, Beltsville, Md.  
 SCOTT, G. W. . . . . Milpitas, Calif.  
 SCOTT, L. B. . . . . Soil Conservation Service, Spartanburg, S. C.  
 SCOTT, L. E. . . . . University of Maryland, College Park, Md.  
 SCOTT, W. C. . . . . Weslaco, Tex.  
 SCUDDER, WALTER G. . . . . Cornell University, Ithaca, N. Y.  
 SEATON, H. L. . . . . Continental Can Co., Chicago, Ill.  
 SEAYER, HENRY B. . . . . 12 Whitehouse Ave., Poughkeepsie, N. Y.  
 SEELYE, GERMAINE. . . . . Box 413, Greenville, R. I.  
 SEELEY, J. G. . . . . Cornell University, Ithaca, N. Y.  
 SEFICK, HAROLD J. . . . . Clemson Agricultural College, Clemson, S. C.  
 SEKHON, B. S. . . . . Ohio State University, Columbus, Ohio.

- SENN, T. L. .... Clemson Agr. College, Clemson, S. C.  
 SERPA, DIEGO. .... University of California, Davis, Calif.  
 SERR, E. F. .... University of California, Davis, Calif.  
 SHANKS, JAMES B. .... Ohio State University, Columbus, Ohio.  
 SHARPE, RALPH H. .... U. S. Pecan Exp. Sta. R. D. 1, Shreveport, La.  
 SHAULIS, NELSON J. .... New York State Experiment Station, Geneva, N. Y.  
 SHAW, E. J. .... 412 West Sixth St., Los Angeles, Calif.  
 SHAW, J. K. .... Massachusetts, State College, Amherst, Mass.  
 SHELTON, R. F. .... Texas Experiment Station, Tyler, Tex.  
 SHEPARD, P. H. .... Missouri Fruit Experiment Sta., Mountain Grove, Mo.  
 SHERWOOD, C. E. .... Michigan State College, East Lansing, Mich.  
 SHIFRIS, OVED. .... Doylestown, Pa.  
 SHOEMAKER, J. S. .... Ontario Agricultural College, Guelph, Canada.  
 SHOWALTER, ROBERT K. .... Florida Experiment Station, Gainesville, Fla.  
 SHUTAK, V. G. .... Rhode Island State College, Kingston, R. I.  
 SIDWELL, A. P. .... Libby, McNeill & Libby, Maunaloa, Molokai, T. H.  
 SIEGEL, TOVAH. .... Heiruth American Beth, Kfar Vitkin, Palestine.  
 SIEGELMAN, HAROLD W. .... University of California, Los Angeles 24, Calif.  
 SIMONS, ROY K. .... University of Delaware, Newark, Del.  
 SIMPSON, ROBERT C. .... Rt. 1, Vincennes, Ind.  
 SINCLAIR, W. B. .... Citrus Experiment Station, Riverside, Calif.  
 SITES, JOHN W. .... Lake Alfred, Fla.  
 SITTON, B. G. .... U. S. Tung Laboratory, Bogalusa, La.  
 SKINNER, H. T. .... Morris Arboretum, Chestnut Hill, Pa.  
 SKOK, JOHN. .... University of Illinois, Urbana, Ill.  
 SLATE, G. L. .... New York State Experiment Station, Geneva, N. Y.  
 SMITH, C. L. .... U. S. Dept. Agr., Box 589, Brownwood, Tex.  
 SMITH, EDWIN. .... U. S. Dept. Agr. Wenatchee, Wash.  
 SMITH, GEORGE E. .... Campbell Soup Co., Riverton, N. J.  
 SMITH, JAMES E., JR. .... University of Missouri, Columbia, Mo.  
 SMITH, JOHN A. .... Box 204, Oliver B. C. Candaa.  
 SMITH, JOHN D. .... R. R. 5, Tipton, Ind.  
 SMITH, ORA. .... Cornell University, Ithaca, N. Y.  
 SMITH, PAUL F. .... U. S. Subtropical Fruit Field Sta., Orlando, Fla.  
 SMITH, PAUL G. .... University of California, Davis, Calif.  
 SMITH, W. W. .... University of New Hampshire, Durham, N. H.  
 SMOCK, R. M. .... Cornell University, Ithaca, N. Y.  
 SNYDER, ELMER. .... U. S. Experiment Vineyard, Fresno, Calif.  
 SNYDER, LEON. .... University of Minnesota, St. Paul, Minn.  
 SNYDER, W. E. .... Cornell University, Ithaca, N. Y.  
 SORESENSEN, HAROLD B. .... Oklahoma A. & M. College, Stillwater, Okla.  
 SOUTHWICK, FRANKLIN W. .... Cornell University, Ithaca, N. Y.  
 SOUTHWICK, LAWRENCE. .... 1422 W. Carpenter St., Midland, Mich.  
 SOUTHWICK, ROY W. .... 563 Murray St., Porterville, Calif.  
 SOUTY, J. .... Sta. D'Arboricul. Fruit., Domaine de la Grande-Ferrade, Pont De La Maye, Gironde, France.  
 SPARKS, WALTER. .... Colorado A. & M. College, Ft. Collins, Colo.  
 STAIR, E. C. .... Purdue University, Lafayette, Ind.  
 STAJANO, ALBERTO BASSO. .... Av. Gral. Flores 2220 Montevideo, Uruguay  
 STALLWORTH, HOUSTON. .... Ft. Valley State College, Ft. Valley, Ga.  
 STANFIELD, J. FISHER. .... Miami University, Oxford, Ohio.  
 STANGLER, BERNARD B. .... Cornell University, Ithaca, N. Y.  
 STANKOVIC, DUSAN. .... University of Belgrade, Zemun, Yugoslavia.  
 STARCHER, DOYLE B. .... P. O. Box 811, Chelan, Wash.  
 STARK, ARVIL L. .... 2225 S. 5th St., East Salt Lake City, Utah.  
 STARK, F. C., JR. .... University of Maryland, College Park, Md.  
 STARK, PAUL, JR. .... Louisiana, Mo.  
 STEELMAN, C. H., JR. .... Rt. 2, Box 2-316, Princeton, N. J.  
 STEINBAUER, C. E. .... Plant Industry Station, Beltsville, Md.  
 STEUK, WILLIAM K. .... Rt. 2, Sandusky, Ohio.  
 STEVENS, W. R. .... Bastia Hill, Wanganui, N. Z.  
 STEWART, WM. S. .... University of California, Riverside, Calif.  
 STIER, H. L. .... 101 Barron St., Takoma Park, Md.

- STOUT, A. B. . . . . New York Botanical Garden, New York City.  
 STOUT, G. J. . . . . University of Florida, Gainesville, Fla.  
 STOUTEMYER, V. T. . . . . University of California, Los Angeles 24, Calif.  
 STRUCKMEYER, B. ESTHER. . . . . University of Wisconsin, Madison, Wis.  
 STUART, N. W. . . . . Plant Industry Station, Beltsville, Md.  
 STUCKEY, H. P. . . . . Georgia Experiment Station, Experiment, Ga.  
 SUDDS, R. H. . . . . West Virginia University, Morgantown, W. Va.  
 SWANSON, CLARK H. . . . . Rt. 2, Box 110C, Escalon, Calif.  
 SWARTLEY, J. C. . . . . 496 Bethlehem Pike, Philadelphia, Pa.  
 SWEET, R. D. . . . . Cornell University, Ithaca, N. Y.  
 SWIM, H. C. . . . . Ontario, Calif.  
 SWINGLE, C. F. . . . . Peninsular Experiment Sta., Sturgeon Bay, Wisc.  
 SYAMAL, NIRODE BARON. . . . . University of California, Davis, Calif.  
 SYLVAIN, PIERRE. . . . . UNRRA 370 N. Soo Chou Rd., Shanghai, China.
- TAI, EGBERT A. . . . . Department of Agriculture, Kingston, Jamaica.  
 TALBERT, T. J. . . . . University of Missouri, Columbia, Mo.  
 TATE, H. D. . . . . Agricultural Research Lab., Bethany, Conn.  
 TAWSE, W. J. . . . . 5559 Terrebonne Ave., Montreal, Canada.  
 TAYLOR, R. H. . . . . 1400 Tenth St., Sacramento, Calif.  
 TEAGUE, C. P. . . . . 309 Rimpau Ave., Corona, Calif.  
 TESKE, A. H. . . . . Virginia A. & M. College, Blacksburg, Va.  
 TEWFIG, SALAH-EL-DIN. . . . . P. O. Box 126, College Park, Md.  
 TEZIER, FRERES. . . . . 27 Ave. Gambetta, Valence, (Drome) France.  
 THOMAS, H. REX. . . . . Plant Industry Station, Beltsville, Md.  
 THOMAS, WALTER. . . . . Pennsylvania State College, State College, Pa.  
 THOMPSON, A. H. . . . . U. S. Dept. Agr., Wenatchee, Wash.  
 THOMPSON, H. C. . . . . Cornell University, Ithaca, N. Y.  
 THOMPSON, MILLER. . . . . Box 136, Conyers, Ga.  
 THOMPSON, R. C. . . . . U. S. Dept. Agr., Washington, D. C.  
 THORNTON, N. C. . . . . Carbide & Carbon Chem. Corp., New York, N. Y.  
 THORNTON, S. F. . . . . F. S. Royster Guano Co., Norfolk, Va.  
 TICH0, ROBERT. . . . . P. O. Box 264, Jerusalem, Palestine.  
 TIEDJENS, V. A. . . . . Virginia Truck Experiment Sta., Norfolk, Va.  
 TILLSON, ALBERT H. . . . . 1022 N. Edison St., Arlington, Va.  
 TING, MRS. S. V. . . . . University of Nanking, Nanking, China.  
 TING, S. V. . . . . University of Nanking, Nanking, China.  
 TITUS, JOHN S. . . . . Michigan State College, East Lansing, Mich.  
 TOMKINS, JOHN P. . . . . New York State Experiment Station, Geneva, N. Y.  
 TOOLE, E. H. . . . . Plant Industry Station, Beltsville, Md.  
 TOWNSEND, P. C. . . . . Selbyville, Del.  
 TRAUB, H. P. . . . . Plant Industry Station, Beltsville, Md.  
 TROTTER, A. R. . . . . Robstown, Tex.  
 TUCKER, W. C. . . . . American Embassy, Rio de Janeiro, Brazil.  
 TUFTS, W. P. . . . . University of California, Davis, Calif.  
 TUKEY, H. B. . . . . Michigan State College, East Lansing, Mich.  
 TUKEY, LOREN. . . . . Michigan State College, East Lansing, Mich.  
 TUKEY, RONALD B. . . . . Michigan State College, East Lansing, Mich.  
 TURNQUIST, O. C. . . . . University of Minnesota, St. Paul, Minn.  
 TURRELL, FRANKLIN M. . . . . University of California, Riverside, Calif.  
 TURRENTINE, JOHN W. . . . . American Potash Inst., Washington, D. C.  
 TUSSING, E. B. . . . . Ohio State University, Columbus, Ohio.
- ULRICH, ALBERT. . . . . University of California, Berkeley, Calif.  
 UPSHALL, W. H. . . . . Vineland Station, Ontario, Canada.  
 URE, C. RAY. . . . . Morden, Manitoba.
- VAILE, J. E. . . . . University of Arkansas, Fayetteville, Ark.  
 VAN AMBURG, WALLACE. . . . . Husum, Wash.  
 VAN BLARICOM, L. O. . . . . South Carolina Experiment Station, Clemson, S. C.  
 VANDEMARK, JOSEPH S. . . . . Fairgrove, Mich.  
 VANDERKAL, DIRK J. . . . . 444 Newton St., San Fernando, Calif.  
 VAN DOREN, ARCHIE. . . . . 1817 "B" St., Pullman, Wash.  
 VAN GELUWE, JOHN. . . . . Terrace Hill, Ithaca, N. Y.

- VAN HORN, C. W. . . . . University Experiment Sta., Yuma, Ariz.  
 VANNAH, H. P. . . . . Box 200, Pisgah Forest, N. C.  
 VAN OVERBEEK, J. . . . . Modesto, Calif.  
 VANSELOW, A. P. . . . . University of California, Riverside, Calif.  
 VEERHOFF, OTTO. . . . . 1512 Conn. Ave., N. W., Washington, D. C.  
 VERNER, LEIF. . . . . University of Idaho, Moscow, Idaho.  
 VIERHELLER, A. F. . . . . University of Maryland, College Park, Md.  
 VINCENT, C. L. . . . . Washington State College, Pullman, Wash.  
 VOLZ, E. C. . . . . Iowa State College, Ames, Ia.
- WADE, B. L. . . . . U. S. Vegetable Breeding Lab., Charleston, S. C.  
 WADHAMS, CORINNE. . . . . Rowayton, Conn.  
 WADLEIGH, C. H. . . . . U. S. Salinity Lab., Riverside, Calif.  
 WALKDEN, H. . . . . Derbyshire Rd., Manchester, England.  
 WALKER, JOHN. . . . . Dominion Forest Nursery Sta., Indian Head, Sask.  
 WALKER, KENNETH. . . . . Agricultural Experiment Station, Pullman, Wash.  
 WALKER, L. C. . . . . Lampassa, Texas.  
 WALLACE, M. D. . . . . Brigham Young University, Provo, Utah.  
 WALTMAN, C. S. . . . . University of Kentucky, Lexington, Ky.  
 WANDER, I. W. . . . . Citrus Experiment Station, Lake Alfred, Fla.  
 WARE, L. M. . . . . Alabama Polytechnic Institute, Auburn, Ala.  
 WARING, J. H. . . . . University of Maine, Orono, Me.  
 WARNE, L. G. G. . . . . University of Manchester, Manchester, England.  
 WARNER, R. M. . . . . California Fig Institute, 208 Mason Bldg., Fresno 1, Calif.
- WARREN, G. F., JR. . . . . University of Wisconsin, Madison, Wis.  
 WATSON, DONALD P. . . . . Cornell University, Ithaca, N. Y.  
 WATSON, ROBERT R. . . . . P. O. Box 129, Twin Falls, Idaho.  
 WATT, A. W. . . . . P. O. Box 70, West Summerland, B. C.  
 WATTS, G. S. . . . . Bellwood, Pa.  
 WATTS, R. L. . . . . Pennsylvania State College, State College, Pa.  
 WATTS, VICTOR M. . . . . University of Arkansas, Fayetteville, Ark.  
 WAUGH, J. G. . . . . California Institute of Technology, Pasadena, Calif.  
 WEBBE, W. E. . . . . Box 173, Barrington, Ill.  
 WEEKS, WALTER D. . . . . University of Massachusetts, Amherst, Mass.  
 WEINARD, E. F. . . . . University of Illinois, Urbana, Ill.  
 WEINBERGER, J. H. . . . . U. S. Hort. Laboratory, Ft. Valley, Ga.  
 WELCH, J. E. . . . . University of California, Davis, California.  
 WELLENSIEK, S. J. . . . . Wageningen, Gelderland, Netherlands.  
 WELLINGTON, J. W. . . . . U. S. Dept. Agr., Washington, D. C.  
 WELLINGTON, R. . . . . New York Experiment Station, Geneva, N. Y.  
 WENT, F. W. . . . . California Institute of Technology, Pasadena, Calif.  
 WERNER, H. O. . . . . University of Nebraska, Lincoln, Neb.  
 WESTER, H. V. . . . . Department of Interior, Washington, D. C.  
 WESTER, R. E. . . . . Plant Industry Station, Beltsville, Md.  
 WESTOVER, K. C. . . . . West Virginia University, Morgantown, W. Va.  
 WHALEY, W. G. . . . . University of Texas, Austin, Texas.  
 WHITAKER, T. W. . . . . Box 150, LaJolla, Calif.  
 WHITE, D. G. . . . . U. S. Subtropical Fruit Sta., Orlando, Fla.  
 WHITE, HAROLD E. . . . . Massachusetts Exp. Sta., Cedar Hill, Waltham, Mass.  
 WHITE, R. H. . . . . Box 93, Harlingen, Texas.  
 WHITEHOUSE, W. E. . . . . Plant Industry Station, Beltsville, Md.  
 WHITEMAN, T. W. . . . . Plant Industry Station, Beltsville, Md.  
 WHITE-STEVENS, R. H. . . . . 247 Park Ave., New York City.  
 WHITTINGER, C. B. . . . . Department of Agriculture, Mount Vernon, Wash.  
 WIGGANS, C. C. . . . . University of Nebraska, Lincoln, Neb.  
 WIGGIN, W. W. . . . . Ohio University, Athens, Ohio.  
 WILCOX, J. C. . . . . Dominion Experiment Sta., Summerland, B. C.  
 WILDE, JOHN E. . . . . Blissfield, Mich.  
 WILLIAMS, CARLOS, F. . . . . North Carolina State College, Raleigh, N. C.  
 WILLIAMS, H. HAMILTON. . . . . 648 Stanford Ave., Los Angeles, Calif.  
 WILLIAMS, W. O. . . . . University of California, Davis, Calif.  
 WILSON, W. F., JR. . . . . Fruit and Truck Experiment Sta., Hammond, La.  
 WINDHAM, STEVE L. . . . . Mississippi State College, State College, Miss.

WINGERT, JOHN B. ....	343 So. Dearborn Street, Chicago, Ill.
WINKLER, A. J. ....	University of California, Davis, Calif.
WINSTON, J. R. ....	U. S. Dept. Agr., Orlando, Fla.
WINTER, F. L. ....	205 Church St., New Haven, Conn.
WINTER, J. D. ....	University of Minnesota, St. Paul, Minn.
WINTERS, HAROLD F. ....	Federal Experiment Sta., U.S.D.A., Mayaguez, P. R.
WISCHHUSEN, J. F. ....	15031 Shore Acres Dr., Cleveland, Ohio.
WITHROW, ALICE P. ....	Purdue University, Lafayette, Ind.
WITTWER, S. H. ....	Michigan State College, East Lansing, Mich.
WOLF, EMIL A. ....	Purdue University, Lafayette, Ind.
WOLFE, H. S. ....	University of Florida, Gainesville, Fla.
WOOD, J. F. ....	1002 Sec. Natl. Bank Bldg., Houston, Texas.
WOOD, M. N. ....	Box 1146, Sacramento, Calif.
WOODARD, OTIS ....	Georgia Coastal Plain Exp. Sta., Tifton, Ga.
WOODBURY, C. G. ....	National Canners' Association, Washington, D. C.
WOODBURY, GEORGE W. ....	1001 West Seneca St., Ithaca, N. Y.
WOODS, J. J. ....	Dominion Experimental Sta., Saanichton, B. C.
WORK, PAUL. ....	Cornell University, Ithaca, N. Y.
WRIGHT, R. C. ....	Plant Industry Station, Beltsville, Md.
WYMAN, DONALD ....	Arnold Arboretum, Jamaica Plains, Mass.
YARGER, L. A. ....	South Dakota State College, Brookings, S. D.
YARNELL, S. H. ....	U. S. Regional Vegetable Breeding Lab., Charleston, S. C.
YATES, H. O., JR. ....	New Camden Co. Vocational Sch. Merchantville, N. J.
YEAGER, A. F. ....	University of New Hampshire, Durham, N. H.
YEATMAN, JOHN N. ....	University of California, Los Angeles, Calif.
YOPP, HERMAN J. ....	Yopp Seed Co., Paducah, Ky.
YOUNG, ROBERT E. ....	Massachusetts Experiment Sta., Cedar Hill, Waltham, Mass.
YOUNG, ROGER S. ....	Michigan State College, East Lansing, Mich.
ZARGER, THOMAS G. ....	Tennessee Valley Authority, Norris, Tenn.
ZIELINSKI, QUENTIN. ....	Oregon State College, Corvallis, Oregon.
ZIMMERMAN, FLOYD S. ....	641 Washington St., New York City.
ZIMMERMAN, P. W. ....	Boyce-Thompson Inst., Yonkers, N. Y.
ZUCKER, ISABEL. ....	1708 Crooks Rd., Royal Oaks, Mich.

A. & M. College of Texas, College Station, Texas.  
The Clemson Agrl. College, Clemson, South Carolina.  
Louisiana St. University, Box 2474, University, La.  
Michigan State College, East Lansing, Mich.  
Purdue University, Lafayette, Ind.  
Wisconsin State Hort. Soc., Madison, Wisc.



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